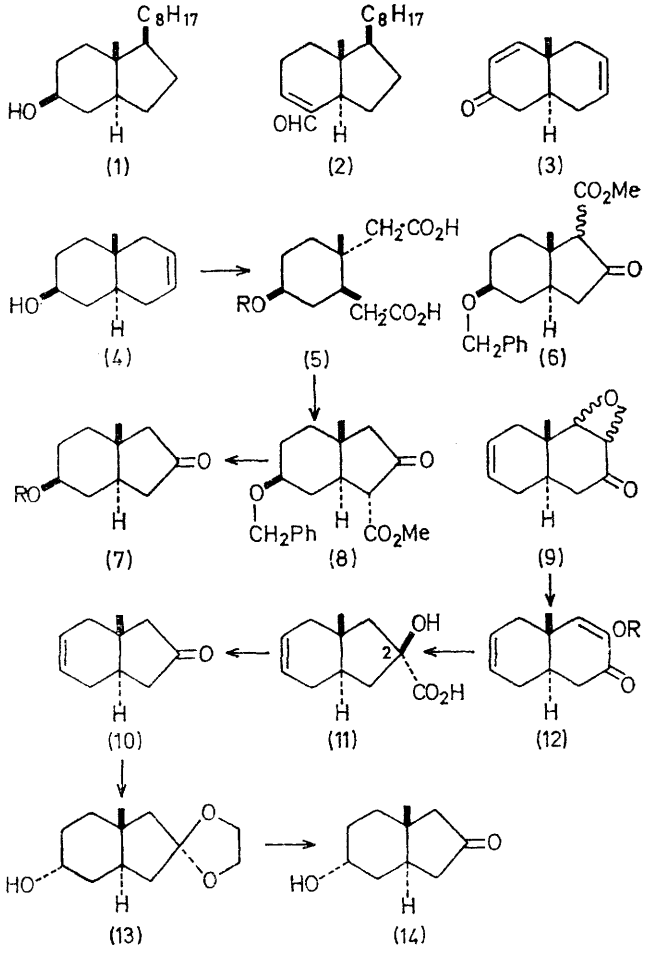
Calciferol and its Relatives. Part X.[1] Ring-contraction Routes to Some 8-Methyl-*trans*-perhydroindanones

By T. M. Dawson, P. S. Littlewood, B. Lythgoe,* T. Medcalfe, M. W. Moon, and P. M. Tomkins, Department of Organic Chemistry, The University, Leeds LS2 9JT

Methods based on a ring-contraction of cyclic αβ-epoxy-ketones to give α-hydroxy-acids are used for the preparation of some 8-methyl-*trans*-perhydroindanone derivatives of possible interest in connection with the synthesis of 9,10-*seco*-steroids. They include the unsaturated ketones (10) and (22), and the hydroxy-ketones (14), (21), (46), and (49).

8-Methyl-*trans*-perhydroindane derivatives containing a keto-group in the cyclopentane ring at position 1 or 2 and a hydroxy-group in the cyclohexane ring at position 5 or 4, are of potential value in the synthesis of 9,10-*seco*-steroids; the keto-group can, in principle, be used to promote the introduction of the future C-17 side-chain, either by carbonyl addition at a 1-ketone, or by alkylation of a 2-ketone. The relevance of a hydroxy-group at position 4 is apparent from the use of (+)-4-hydroxy-8-methyl-*trans*-perhydroindan-1-one as an intermediate in a synthesis[2] of vitamin D_3, and the 5-hydroxyperhydroindane (1) † has been transformed[3] into the αβ-unsaturated aldehyde (2),† from which the synthesis[1] of tachysterol$_3$ was effected. We have therefore explored some routes to hydroxyperhydroindanones of the kind in question.

5-Hydroxyperhydroindanones.—Although the work now detailed employed racemic materials, it was planned with a view to the use of optically active compounds. For this reason the hexalone[4] (3), which can be obtained in optically active[5] as well as racemic forms, was an attractive starting material. Djerassi and his colleagues[6] have already used one of the enantiomers of this ketone to prepare an optically active form of the hydroxyperhydroindanone (7; R = H); they first reduced the enone system to give an alcohol of the type (4), from which a diacetic acid of the type (5) was then prepared, and subjected to Dieckmann cyclisation. We thought it of interest to determine whether by using this route a β-keto-ester such as (6) could be prepared, since that compound should lend itself to the introduction of the iso-octyl side-chain. We therefore modified Djerassi's method so as to obtain the free diacetic acid (5; R = H), and then the benzyl ether (5; R = CH_2Ph). When cyclised by the Dieckmann method the dimethyl ester of the latter gave mainly one (crystalline) β-keto-ester, which the n.m.r. data identified as the isomer (8); this direction of cyclisation presumably reflects the relative accessibility to bases of the two activated methylene groups in the dimethyl ester. From the β-keto-ester (8) the benzyloxy-ketone (7; R = CH_2Ph) was prepared; catalytic removal of the benzyl group then gave the 5β-hydroxy-ketone (7; R = H).



A second route to this ketone involved the alkaline decomposition of the epoxides (9), obtained by the action of alkaline hydrogen peroxide on the hexalone (3). In general, such reactions[7] lead either to ring contraction to give a γ-hydroxy-acid, or else to the formation of an enolised α-diketone or its derivative

† Structures (1) and (2) denote optically active forms; the remainder represent racemates.

[1] Part IX, R. S. Davidson, S. M. Waddington-Feather, D. H. Williams, and B. Lythgoe, *J. Chem. Soc.* (*C*), 1967 2534.

[2] H. H. Inhoffen, G. Friedrich, D. Kampe, and O. Berges, *Chem. Ber.*, 1959, **92**, 1772; and references there cited.

[3] R. S. Davidson, P. S. Littlewood, T. Medcalfe, S. M. Waddington-Feather, D. H. Williams, and B. Lythgoe, *Tetrahedron Letters*, 1963, 1413.

[4] R. B. Woodward, F. Sondheimer, D. Taub, K. Heusler, and W. M. MacLamore, *J. Amer. Chem. Soc.*, 1952, **74**, 4223.

[5] A. J. Speziale, J. A. Stephens, and Q. E. Thompson, *J. Amer. Chem. Soc.*, 1954, **76**, 5011.

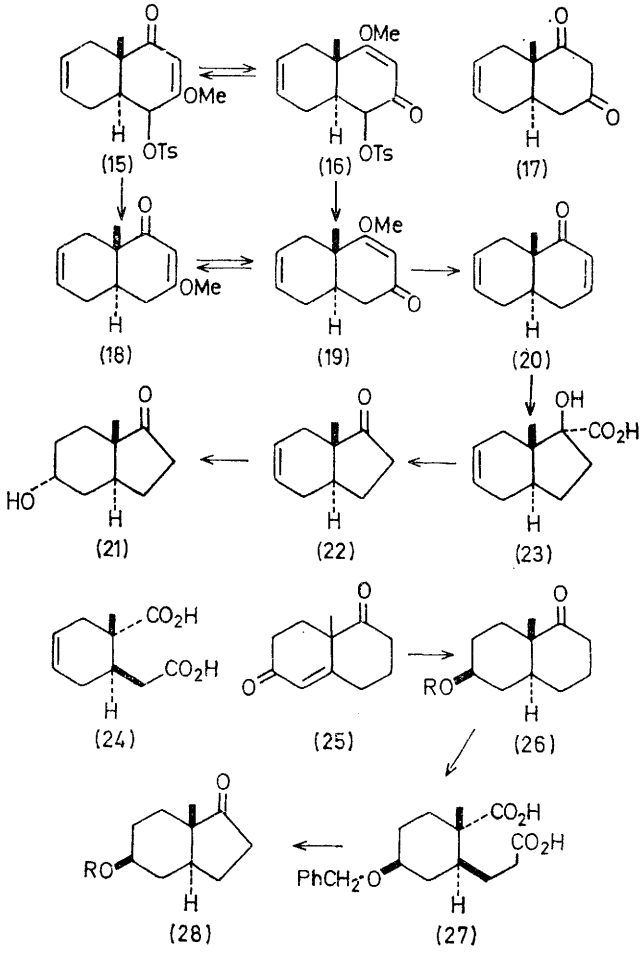
[6] C. Djerassi, D. Marshall, and T. Nakano, *J. Amer. Chem. Soc.*, 1958, **80**, 4853.

[7] H. O. House and W. F. Gilmore, *J. Amer. Chem. Soc.*, 1961, **83**, 3972; W. Reusch and R. LeMahieu, *ibid.*, 1963, **85**, 1669.

with retention of ring-size. Here, when methanolic potassium hydroxide was used, the second of these alternative paths was followed, giving the crystalline enol ether (12; R = Me) in over 90% yield. From it the enolised α-diketone (12; R = H) was readily obtained by hydrolysis with acid. It would clearly be possible to cleave this diketone to 1-methylcyclohex-4-ene-1,2-diacetic acid, from which the hexahydroindenone (10) could be obtained by the Dieckmann method. However, an easier route to this hexahydroindenone used a benzilic acid rearrangement of a type which has already found restricted use [8] in the steroid field as a method of ring contraction. Vigorous alkaline treatment of the diketone (12; R = H) gave the α-hydroxy-acid (11) in 80% yield; its C-2 configuration is assigned on conformational [9] grounds. For preparative purposes it was convenient to heat the mixed epoxides (9) with aqueous alkali in dioxan; the enol (12; R = H) was first formed and then rearranged to the hydroxy-acid (11). Cleavage with lead tetra-acetate then gave the hexahydroindenone (10) in about 55% overall yield from the hexalone (3).

The 5-hydroxy-group was introduced into the ketone (10) as follows. Its ethylene acetal gave with peroxy-acid mainly the 5α,6α-epoxide converted by reaction with lithium aluminium hydride into the 5α-hydroxy-acetal (13); the free hydroxy-ketone (14) was then obtained by hydrolysis with acid. Alternatively, oxidation of the hydroxy-acetal (13) with chromic oxide in pyridine, followed by reduction with sodium borohydride in ethanol, and subsequent hydrolysis of the acetal group, provided the 5β-hydroxy-ketone (7; R = H), identical with material obtained by the modified Djerassi route. The two methods complement each other in the sense that their application to the two *different* enantiomers of the hexalone (3) would yield the *same* enantiomer of the hydroxy-ketone (7; R = H).

In order to prepare the hexahydroinden-1-one (22) the αβ-unsaturated ketone (20) was required. One of its optically active forms has been prepared,[10] but the methods used have not, so far as we are aware, been published. We obtained the racemate (20) as follows. The Monsanto variant [5] of Woodward's [4] route uses the tosylate (15) as the precursor of the enol ether (18) and the hexalone (3). We found that when the tosylate (15) was heated in methanol with toluene-*p*-sulphonyl chloride, it gave in high yield the isomeric tosylate (16); use of ethanol as solvent gave the corresponding ethyl ether. The toluene-*p*-sulphonyl chloride appeared to act by providing hydrogen chloride and toluene-*p*-sulphonic acid; these could be used instead to effect the same changes. Treatment of the tosylate (16) with zinc and acetic acid gave the enol ether (19). When either (19) or its isomer (18) was treated in methanol with toluene-*p*-sulphonyl chloride, a mixture of compounds (18) (*ca.* 70%) and (19) (*ca.* 30%) (g.l.c.) was produced. Speziale and his colleagues [5] found that boiling the diketone (17) with benzene and methanol containing toluene-*p*-sulphonic acid gave about 70% of the enol ether (18), and a mother liquor which appeared to contain the isomer (19). It seems to us possible that in acidic methanol the ethers (18) and (19) may be interconvertible directly, *i.e.* without the intervention of the free diketone; and a similar interconversion of the isomers (15) and (16) probably takes place under our reaction conditions. It is, however, remarkable that at equilibrium the isomer (18) should predominate, whilst of the two tosylates the isomer (16) should be favoured; presumably, conformational factors are involved.



Reduction of the ether (19) with lithium aluminium hydride, followed by treatment with acid, gave the αβ-unsaturated ketone (20). The corresponding αβ-epoxy-ketones were heated with alkali to give the hydroxy-acid (23). This was converted, by methods already mentioned, into the hexahydroindenone (22), the 5α-hydroxy-ketone (21), and the 5β-hydroxy-ketone (28; R = H).

[8] R. Hirschmann, G. A. Bailey, R. Walker, and J. M. Chemerda, *J. Amer. Chem. Soc.*, 1959, **81**, 2822; M. Rajic, T. Rüll, and G. Ourisson, *Bull. Soc. chim. France*, 1961, 1213.

[9] V. Georgian and N. Kundu, *Tetrahedron*, 1963, **19**, 1037.

[10] By Dr. W. S. Knowles and his colleagues of the Monsanto Chemical Co., St. Louis, Missouri; see footnote 12 in C. Djerassi, R. Riniker, and B. Riniker, *J. Amer. Chem. Soc.*, 1956, **78**, 6363.

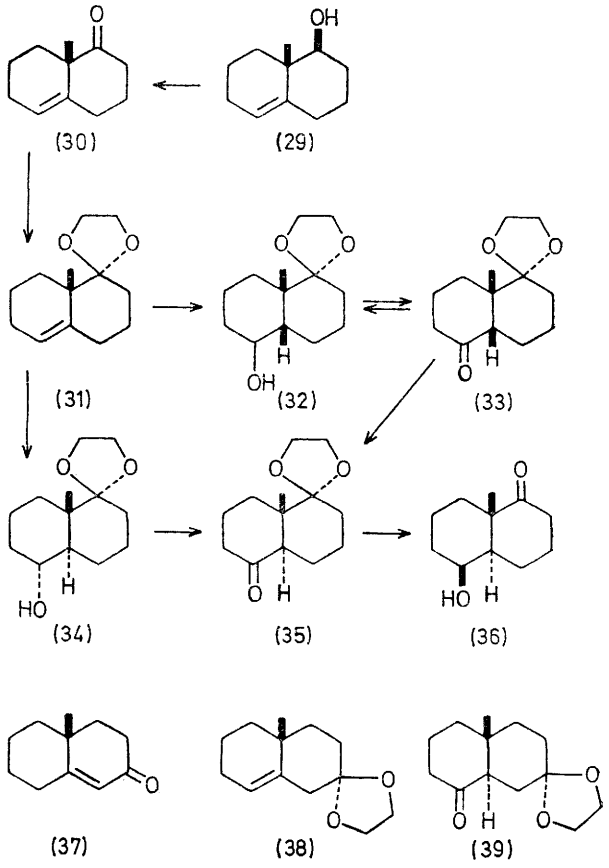
An alternative route (less efficient) to the hexahydroindenone (22) which we explored earlier is as follows. Hypobromite oxidation of the β-diketone (17) gave the dibasic acid (24). The tertiary half-methyl ester was subjected to homologation of the acetic acid residue by the Arndt–Eistert method which gave methyl 16-methoxycarbonyl-6-methylcyclohex-3-enepropionic acid; this was cyclised by the Dieckmann method to the ketone (22). We also obtained the 5β-hydroxy-ketone (28; R = H) from the Wieland–Miescher [11] ketone (25). Its monoethylene acetal [12] gave on Birch reduction the ethylene acetal of the hydroxy-ketone (26; R = H); benzylation and hydrolysis gave the ketone (26; R = CH_2Ph). Its furfurylidene derivative was oxidised [13] to the acid (27), which was cyclised to the ketone (28; R = CH_2Ph). Catalytic hydrogenolysis then gave the hydroxy-ketone (28; R = H).

4-Hydroxyperhydroindanones.—One such compound, the 1-one (49), has already been obtained by synthesis,[14] but the low yield (*ca.* 0·2% from methyl 2-methyl-4-oxocyclohex-2-enecarboxylate) makes the method of limited use for preparative purposes. The routes now described, although still rather long, give the hydroxyperhydroindanones (46) and (49) in yields better than 4% from the readily available [15] octalone (37).

Initially we hoped to base our work upon the unsaturated acetal (31), the preparation of which from the Wieland–Miescher ketone (25), *via* the intermediates (29) and (30), is described in the Experimental section. Treatment of the acetal (31) with diborane in tetrahydrofuran, followed by decomposition with alkaline hydrogen peroxide, gave a mixture of two main products, as shown by t.l.c. Chromatography permitted the isolation of the major, less strongly adsorbed product, which we showed to be the hydroxy-acetal (32); the more strongly adsorbed product which we showed to be the hydroxy-acetal (34), was enriched by this process, but could not be obtained free from the isomer (32).

Hydrolysis of the acetal (32) with acid gave a crystalline hydroxy-ketone which served to characterise it. Oxidation of the acetal (32) with chromic oxide in pyridine gave an oily keto-acetal (33), $\nu_{max.}$ 1710 and 962 cm.$^{-1}$; on reduction with sodium borohydride this gave back the hydroxy-acetal (32), as shown by t.l.c. and by hydrolysis to the crystalline hydroxy-ketone. When the keto-acetal (33) was treated with ethanolic sodium ethoxide, it was changed into an isomeric keto-acetal (35), $\nu_{max.}$ 926 cm.$^{-1}$ (*cf.* $\nu_{max.}$ 962 cm.$^{-1}$ of its precursor). When the new keto-acetal was reduced with sodium borohydride, it gave a crude hydroxy-acetal which was different from both compounds (32) and (34) (t.l.c.), and which provided on hydrolysis the crystalline hydroxy-ketone (36).

Chromatographic fractions containing the more strongly adsorbed of the two products of the hydroboration reaction were oxidised with chromic oxide in pyridine, a procedure which did not isomerise the keto-acetal (33), to give a mixture of the keto-acetals (33) and (35), $\nu_{max.}$ 962 and 926 cm.$^{-1}$. Reduction of the mixture with



sodium borohydride, followed by hydrolysis with acid, gave a mixture from which the crystalline hydroxy-ketone (36) was isolated by chromatography. This demonstrates the presence of the hydroxy-acetal (34) in the original hydroboration–hydration product.

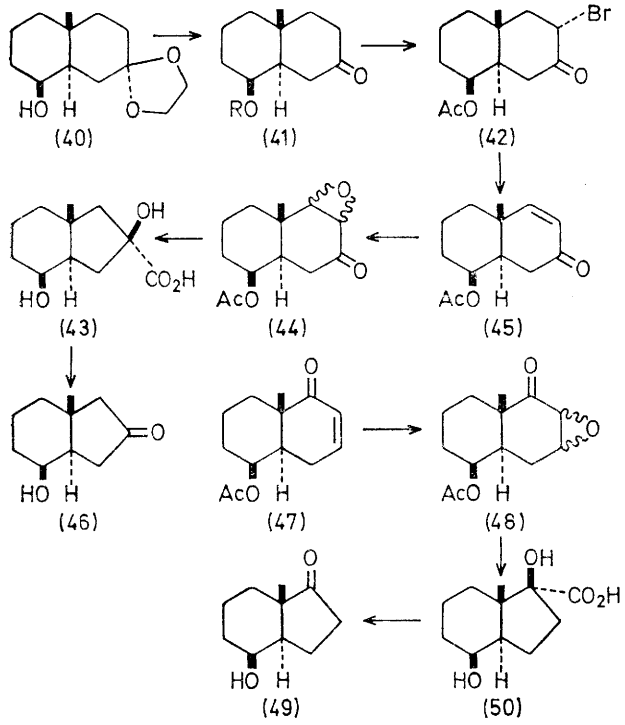
In the hydroxy-acetal (34) the hydroxy-group and the ring-junction hydrogen atom must be *cis*-related. The isomeric acetal, corresponding to the ketone (36), has the same configuration at the ring junction, but is epimeric at the hydroxylic centre, so the hydroxy-group and the ring-junction hydrogen atom are *trans*-related; the latter should therefore not be affected when the benzoate of the hydroxy-ketone (36) is pyrolysed. In fact, when the product of this pyrolysis was hydrogenated, *trans*-9-methyl-1-decalone was obtained. Compounds (34), (35), and (36) therefore have a *trans* ring junction. This agrees with the observation that of the keto-acetals (33) and (35) the latter is the more stable.

Based on these observations a method for the prepara-

[11] P. Wieland and K. Miescher, *Helv. Chim. Acta*, 1950, **33**, 2215; *Org. Synth.*, 1961, **41**, 57.
[12] E. J. Corey, M. Ohno, R. B. Mitra, and P. A. Vatakencherry, *J. Amer. Chem. Soc.*, 1964, **86**, 478.
[13] W. S. Johnson, B. Bannister, R. Pappo, and J. E. Pike, *J. Amer. Chem. Soc.*, 1956, **78**, 6354.
[14] H. H. Inhoffen, S. Schütz, P. Rossberg, O. Berges, K.-H. Nordsiek, H. Plenio, and E. Höroldt, *Chem. Ber.*, 1958, **91**, 2626.
[15] J. A. Marshall and W. I. Fanta, *J. Org. Chem.*, 1964, **29**, 2501.

tion of the hydroxy-ketone (36) was worked out. This compound was obtained in over 12% yield from the acetal (31), which was itself available in about 22% yield from the Wieland–Miescher ketone. These yields were regarded as too low to justify proceeding with the work, and it was resumed only after Marshall and his colleagues [16] described the preparation of the keto-acetal (39) from the unsaturated acetal (38), which their work made readily available *via* the octalin (37). Their route to the keto-acetal (39) was similar in outline to our route to the isomeric compound (35), but was much superior in its quantitative aspects, and we have therefore used it as the basis for our further experiments. There is one interesting difference between the results obtained during the hydroboration–hydration of the two unsaturated acetals (31) and (38). Marshall and his colleagues found no evidence for *cis*-anti-Markownikoff addition of diborane from the side of the molecule *trans* to the angular methyl group in the acetal (38), and they pointed out that the axial oxygen atom of the acetal group should make such addition more difficult. The same theoretical considerations appear to apply to the acetal (31), but we found that although compound (32) was the major product from it, the isomer (34) was also formed in considerable amounts; admittedly no exact quantitative determinations were made.

By reduction of the keto-acetal (39) with sodium borohydride we obtained the crystalline hydroxy-acetal



(40) in *ca.* 25% yield from the octalone (37); hydrolysis then gave the hydroxy-ketone (41; R = H). Its acetate (41; R = Ac) was converted successively by standard methods into the bromo-ketone (42), the oily αβ-unsaturated ketone (45), and the epoxide(s) (44). The formation of the last-named compound(s) required the use of alkali, and it was of interest that the acetate group was not affected. Treatment of compound(s) (44) with hot alkali in dioxan gave the crystalline hydroxy-acid (43). Cleavage with lead tetra-acetate provided the hydroxy-ketone (46), which was characterised as the *p*-nitrobenzoate. It was obtained *in ca.* 20% yield from the hydroxy-acetal (40).

By use of Wharton's [17] method, the epoxide (44) was treated with hydrazine hydrate to give a crude allylic alcoholic product, from which, by oxidation with chromic oxide in acetic acid, the αβ-unsaturated ketone (47) was obtained. Its identity was confirmed by the observation that on hydrogenation, followed by hydrolysis with alkali, it gave the hydroxy-ketone (36). Treatment with alkaline hydrogen peroxide converted the enone (47) into a crystalline epoxide (48), which was subjected to vigorous alkaline treatment to give the hydroxy-acid (50). Cleavage of this with lead tetra-acetate then gave the hydroxy-ketone (49), which was characterised as the 3,5-dinitrobenzoate. It was obtained in about 17% yield from the hydroxy-acetal (40).

EXPERIMENTAL

Unless otherwise specified, light absorption data refer to solutions in ethanol, and n.m.r. data to solutions in deuteriochloroform.

The Hydroxy-acid (5; R = H).—Sodium (20 g.) was added in small pieces during 1·5 hr. to a stirred and cooled (−70°) solution of the ketone (3) (2 g.) in ether (40 c.c.), methanol (120 c.c.), and liquid ammonia (200 c.c.). Stirring was continued for 1 hr., ammonium chloride (32 g.) was added, and the ammonia was allowed to evaporate. The solution was concentrated under reduced pressure, water was added, and the oily product (1·82 g.) was isolated with ether. The 8a-*methyl*-Δ^2-*octalin*-6-*ol* (4) 3,5-*dinitrobenzoate* (3·7 g.) had m.p. 109—110° (from ethanol) (Found: C, 59·75; H, 5·55; N, 7·75. $C_{18}H_{20}N_2O_6$ requires C, 60·0; H, 5·6; N, 7·7%).

A portion (2 g.) in ethyl acetate (80 c.c.) was ozonised at −70° till the solution was blue. After the addition of glacial acetic acid (1 c.c.) and 30% hydrogen peroxide (0·5 c.c.) it was kept at room temperature for 0·5 hr. and then warmed briefly to 50°; most of the ethyl acetate was then removed under reduced pressure. More acetic acid (1 c.c.) and 30% hydrogen peroxide (0·5 c.c.) were added, and the mixture was kept at 50° for 16 hr. and then heated at 100° for 1 hr. Removal of the solvents and dilution with water gave the 4-*hydroxy*-1-*methylcyclohexane*-1,2-*diacetic acid* (5; R = H) 3,5-*dinitrobenzoate* (2·2 g.), which formed yellow prisms, m.p. 238—239° (from chloroform–acetone) (Found: C, 51·2; H, 4·9; N, 6·65. $C_{18}H_{20}N_2O_{10}$ requires C, 50·9; H, 4·75; N, 6·6%). Alkaline hydrolysis and continuous extraction of the acidified solution with ether gave the *hydroxy-acid* (5; R = H) (370 mg.) as prisms, m.p. 174—175° (from chloroform–acetone) (Found: C, 57·55; H, 7·65. $C_{11}H_{18}O_5$ requires C, 57·4; H, 7·9%).

[16] J. Marshall, M. T. Pike, and R. D. Carroll, *J. Org. Chem.*, 1966, **31**, 2933; J. A. Marshall, and M. T. Pike *Tetrahedron Letters*, 1965, 3107.

[17] P. S. Wharton and D. H. Bohlen, *J. Org. Chem.*, 1961, **26**, 3615.

The hydroxy-acid (1 g.), powdered potassium hydroxide (10 g.), benzyl chloride (30 c.c.), and toluene (100 c.c.) were heated together under reflux with vigorous stirring for 16 hr.; the mixture was then freed from volatile material by steam distillation and heated for 4 hr. with more potassium hydroxide (40 g. in 200 c.c. of solution). The acidic product was isolated in the usual manner, giving the *benzyl ether* (5; R = CH_2Ph) (870 mg.), m.p. 208—209° (from acetone–light petroleum) (Found: C, 67·5; H, 7·35. $C_{18}H_{24}O_5$ requires C, 67·5; H, 7·55%).

The β-*Keto-ester* (8).—The benzyl ether (1·45 g.) was treated with ethereal diazomethane to give the dimethyl ester, which was heated under reflux under nitrogen for 7 hr. with potassium t-butoxide [from potassium (3 g.)] in t-butyl alcohol (300 c.c.) and benzene (500 c.c.). The solution was kept at 18° for 16 hr., then acidified with 2N-sulphuric acid and extracted with more benzene. Unchanged starting material (150 mg.) was removed by washing the benzene extract with aqueous sodium carbonate and water; evaporation of the dried extract and crystallisation from ether at −15° gave the crude *methyl* 6-*benzyloxy*-3a-*methyl*-2-*oxoperhydroindane*-1-*carboxylate* (8) (940 mg.). It formed needles, m.p. 91—92° (from ether), $\nu_{max.}$ (KCl) 1760 and 1720 cm.$^{-1}$ (Found: C, 71·8; H, 7·4. $C_{19}H_{24}O_4$ requires C, 72·1; H, 7·65%), τ 9·05 (3H, s, 3a-Me) and 7·1 (1H, d, *J* 12 Hz, 1-H*ax* coupled with 7a-H).

5-*Benzyloxy*-7a-*methylperhydroindan*-2-*one* (7; R = CH_2-Ph).—The keto-ester (200 mg.), toluene-*p*-sulphonic acid (1 g.), water (2 c.c.), and acetic acid (10 c.c.) were heated together under reflux in nitrogen for 1 hr. Evaporation and isolation of the neutral material gave the ketone (7; R = CH_2Ph) as an oil (140 mg.), $\nu_{max.}$ 1738 cm.$^{-1}$. The 2,4-*dinitrophenylhydrazone* formed needles (from ethanol), m.p. 199—200° (Found: C, 63·2; H, 5·95; N, 13·2. $C_{23}H_{26}N_4O_5$ requires C, 63·0; H, 6·0; N, 12·8%).

4a,5,8,8a-*Tetrahydro*-3-*methoxy*-4a-*methylnaphthalen*-2(1H)-*one* (12; R = Me).—A solution of the ketone (3) (1·94 g.) and aqueous 4N-sodium hydroxide (1·5 c.c.) in methanol (24 c.c.) was kept at 0° while 20% hydrogen peroxide (2·04 c.c.) was added with stirring, and then at 20° for 20 min. Dilution with water and extraction with benzene gave an oil (2·06 g.), $\nu_{max.}$ 1705 cm.$^{-1}$, consisting of the mixed epoxides (9). A portion (1·04 g.) was heated under reflux for 18 hr. with methanol (150 c.c.) and aqueous 4N-sodium hydroxide (23·2 c.c.). Removal of the solvent and isolation with ether gave the *enol ether* (973 mg.), which formed needles (from light petroleum), m.p. 104—105°, $\lambda_{max.}$ 262 nm. (ε 7000), $\nu_{max.}$ (KCl) 1680, 1653, and 1630 cm.$^{-1}$ (Found: C, 75·0; H, 8·2. $C_{12}H_{16}O_2$ requires C, 75·0; H, 8·4%).

Hydrolysis with hot aqueous ethanolic 2N-hydrochloric acid gave the enolised α-*diketone* (12; R = H) as plates (from light petroleum), m.p. 83—85°, $\lambda_{max.}$ 267 nm. (ε 7500); $\lambda_{max.}$ (in ethanol with an equal volume of aqueous N-sodium hydroxide) 312 nm. (ε 5400), $\nu_{max.}$ (Nujol) 1667 cm.$^{-1}$ (Found: C, 74·0; H, 7·7. $C_{11}H_{14}O_2$ requires C, 74·15; H, 7·9%).

3a,4,7,7a-*Tetrahydro*-2-*hydroxy*-3a-*methylindane*-2-*carboxylic Acid* (11).—(a) The diketone (235 mg.), ethanol (4 c.c.), and 33% aqueous potassium hydroxide (20 c.c.) were heated together under reflux for 90 min. Acidification of the cooled solution and isolation with ether gave a crystalline solid (247 mg.). The *hydroxy-acid* formed needles (202 mg.) (from benzene), m.p. 143—144° (Found: C, 67·25; H, 8·0. $C_{11}H_{16}O_3$ requires C, 67·3; H, 8·2%).

(*b*) The mixed epoxides (9) (2 g.) were heated under reflux for 90 min. with aqueous 20% sodium hydroxide (166 c.c.) and dioxan (15 c.c.), with vigorous stirring. Work-up gave the hydroxy-acid (1·34 g.), m.p. 142—143°.

trans-3a,4,7,7a-*Tetrahydro*-3a-*methylindan*-2-*one* (10).—The hydroxy-acid (1·34 g.) and lead tetra-acetate (3·4 g.) were kept together at 22° in chloroform for 4 hr., and then, following the addition of a little ethylene glycol, for a further 15 min. The solution was washed with water, aqueous sodium carbonate, and water, and then dried and evaporated, giving the ketone as an oil (877 mg.), $\nu_{max.}$ 1740 and 1642 cm.$^{-1}$, which g.l.c. showed to be homogeneous. The 2,4-*dinitrophenylhydrazone* formed needles (from ethanol), m.p. 177—178° (Found: C, 58·15; H, 5·5; N, 17·1. $C_{16}H_{18}N_4O_4$ requires C, 58·2; H, 5·5; N, 17·0%).

6α-*Hydroxy*-3aβ-*methyl*-trans-*perhydroindan*-2-*one* (14).—The hexahydroindenone (10) (755 mg.), ethylene glycol (2 c.c.), and toluene-*p*-sulphonic acid (15 mg.) were heated together in benzene (25 c.c.) for 14 hr. with azeotropic removal of water; evaporation of the cooled and washed solution gave the oily acetal (978 mg.) showing no i.r. carbonyl absorption. A portion (778 mg.) was treated with *m*-chloroperbenzoic acid (1·38 g.) in ether (40 c.c.) at room temperature for 16 hr., giving the *epoxy-acetal* (13)(601 mg.), m.p. 72—73° (from light petroleum) (Found: C, 68·5; H, 8·5. $C_{12}H_{18}O_3$ requires C, 68·6; H, 8·6%).

The epoxide (210 mg.) and lithium aluminium hydride (200 mg.) were kept together in dry ether (30 c.c.) at 20° for 1 hr., and then under reflux for a further 1 hr. After work-up with ethyl acetate and aqueous Rochelle salt the hydroxy-acetal was isolated with ether as an oil (209 mg.). Hydrolysis with 0·7N-sulphuric acid (3 c.c.) and methanol (6 c.c.) gave the hydroxyperhydroindanone (14) as an oil (142 mg.) from which the crude crystalline p-*nitrobenzoate* (252 mg.) was obtained. It formed needles (178 mg.), m.p. 170—171° (from ethanol), $\nu_{max.}$ (KCl) 1735 and 1705 cm.$^{-1}$ (Found: C, 64·4; H, 5·85; N, 4·7. $C_{17}H_{19}NO_5$ requires C, 64·3; H, 6·0; N, 4·4%).

6β-*Hydroxy*-3aβ-*methyl*-trans-*perhydroindan*-2-*one* (7; R = H).—(*a*) The hydroxy-acetal (323 mg.) in pyridine (3 c.c.) was added to a stirred suspension of chromic oxide (783 mg.) in pyridine (8 c.c.). The mixture was kept 4 days at 18° and then poured into water; the product (216 mg.) was isolated by ether from the filtered solution. It was kept for 16 hr. with sodium borohydride (216 mg.) in ethanol (6 c.c.); isolation in the usual way gave an oil (204 mg.) which was hydrolysed with aqueous methanolic sulphuric acid to the oily hydroxy-ketone (119 mg.). The p-*nitrobenzoate* formed needles (95 mg.) (from ethanol), m.p. 118—119°, $\nu_{max.}$ ($CHCl_3$) 1740 and 1718 cm.$^{-1}$ (Found: C, 64·3; H, 6·1; N, 4·65. $C_{17}H_{19}NO_5$ requires C, 64·3; H, 6·0; N, 4·4%).

(*b*) A solution of the benzyl ether (7; R = CH_2Ph) (136 mg.) in ethyl acetate (10 c.c.) containing a drop of concentrated hydrochloric acid was hydrogenated with 5% palladised charcoal (50 mg.). Isolation in the usual way gave the oily hydroxyperhydroindanone (80 mg.) which furnished 103 mg. of crude crystalline p-*nitrobenzoate*. After recrystallisation from ethanol it had m.p. and mixed m.p. 118—119°.

4a,5,8,8a-*Tetrahydro*-4-*methoxy*-4a-*methyl*-1-p-*tolylsulphonyloxynaphthalen*-2(1H)-*one* (16).—The toluene-*p*-sulphonate (15) (1 g.) and toluene-*p*-sulphonyl chloride (0·2 g.) were boiled under reflux in methanol (2·5 c.c.) for 1 hr. The mixture was cooled and the product (0·97 g.), m.p. 135—

139°, was collected. The *toluene*-p-*sulphonate* (16) had m.p. 147·5—148·5° (from acetone) (Found: C, 62·95; H, 5·85; S, 8·9. $C_{19}H_{22}O_5S$ requires C, 63·0; H, 6·1; S, 8·8%).

The corresponding *ethyl ether*, prepared analogously, formed needles (from ethanol), m.p. 160—161° (Found: C, 63·7; H, 6·3; S, 8·1. $C_{20}H_{24}O_5S$ requires C, 63·8; H, 6·4; S, 8·5%).

Reaction of the Enol Ethers (18) *and* (19) *with Toluene*-p-*sulphonyl chloride in Methanol*.—The enol ether (19) (1 g.), toluene-*p*-sulphonyl chloride (0·2 g.), and dry methanol (2·5 c.c.) were heated together under reflux with exclusion of moisture for 1 hr. The mixture was diluted with water and extracted with ether. The extract was washed with aqueous sodium carbonate and with water, and then dried and evaporated, giving an oil (1 g.). G.l.c. showed the presence of two components; *ca.* 72% enol ether (18) and *ca.* 28% (19). Crystallisation of the oil from light petroleum and repeated recrystallisation of the product from the same solvent gave the enol ether (18), m.p. 75—77°.

Similar results were obtained when the enol ether (18) was used as the starting material.

4a,5,8,8a-*Tetrahydro*-8a-*methylnaphthalen*-1(4H)-*one* (20).—To a vigorously stirred suspension of the foregoing ethyl ether (4·5 g.) in glacial acetic acid (6·5 c.c.) containing acetic anhydride (0·5 c.c.), zinc dust (1·7 g.) was added; reaction set in at 80°, and the temperature was kept at 100—110° for 2 hr. The mixture was filtered and the residue was washed with acetic acid; filtrate and washings were poured into water and extracted with ether. Washing the ether extract with aqueous sodium carbonate and acidification of the washings gave the β-diketone (17) (0·43 g.), m.p. 149—151°. Evaporation of the dried ether phase gave the enol ethyl ether (19; Et instead of Me) as an oil (1·68 g.), $\nu_{max.}$ 1657 and 1597 cm.$^{-1}$. The oily methyl ether (19) was similarly prepared.

The ethyl ether (1·67 g.) in dry ether (12 c.c.) was added during 0·5 hr. to a stirred solution of lithium aluminium hydride (214 mg.) in ether (12 c.c.) under nitrogen. After a further 1·5 hr. water was added to the cooled (5°) solution, followed by aqueous sulphuric acid [acid (0·6 c.c.) and water (6 c.c.)]; the aqueous phase was separated and extracted with more ether. The washed and dried ether phases were evaporated, and the residue was heated at 100° for 2·5 hr. with water (1·3 c.c.) and concentrated sulphuric acid (0·21 c.c.), with vigorous agitation. Isolation with ether and distillation at 62—64°/0·1 mm. gave the αβ-unsaturated ketone (20) as an oil (1·05 g.), $\lambda_{max.}$ 225 nm. (ε 7850), $\nu_{max.}$ 1678 cm.$^{-1}$. The 2,4-*dinitrophenylhydrazone* formed needles, m.p. 158—160° (from aqueous acetic acid) (Found: C, 59·2; H, 5·35; N, 16·8. $C_{17}H_{18}N_4O_4$ requires C, 59·6; H, 5·3; N, 16·4%).

trans-3a,4,7,7a-*Tetrahydro*-7a-*methylindan*-1-*one* (22).—The αβ-unsaturated ketone (20) (1 g.) was converted as described for the isomer (3) into a mixture of epoxides (1·04 g.), $\nu_{max.}$ 1708 cm.$^{-1}$. A portion (0·96 g.) was heated under reflux for 12 hr. with sodium hydroxide (20 g.) in dioxan (10 c.c.) and water (80 c.c.). Removal of neutral material, followed by acidification afforded the 3a,4,7,7a-*tetrahydro*-1-*hydroxy*-7a-*methylindane*-1-*carboxylic acid* (23) (0·81 g.), m.p. 142—144°, which separated from benzene in needles, m.p. 150—151° (Found: C, 67·6; H, 8·2. $C_{11}H_{16}O_3$ requires C, 67·3; H, 8·2%).

Cleavage with lead tetra-acetate in chloroform gave in *ca.* 80% yield the oily tetrahydroindanone (22), $\nu_{max.}$ 1742 and 1639 cm.$^{-1}$; it was homogeneous on g.l.c. The 2,4-dinitrophenylhydrazone had m.p. 197—199°, undepressed on admixture with material prepared as described later.

5α-*Hydroxy*-7aβ-*methyl*-trans-*perhydroindan*-1-*one* (21).—The methods used were similar to those described for the isomeric 2-one (14). The tetrahydroindanone (22) (1 g.) was converted into the oily ethylene acetal (1·0 g.). Treatment of the acetal (0·29 g.) with monoperphthalic acid in ether gave an oily mixture of two epoxides in the ratio (g.l.c.) *ca.* 3 : 1. A portion (0·53 g.) was reduced with lithium aluminium hydride, and the crude oily hydroxy-acetal mixture (0·48 g.) was hydrolysed giving a crude oily hydroxy-ketone (0·376 g.), $\nu_{max.}$ 3367 and 1736 cm.$^{-1}$. Reaction with *p*-nitrobenzoyl chloride in pyridine gave the p-*nitrobenzoate* (0·42 g.) of the hydroxy-ketone (21) as needles (from ethyl acetate), m.p. 167—168° (Found: C, 64·4; H, 6·0; N, 4·65. $C_{17}H_{19}NO_5$ requires C, 64·3; H, 6·0; N, 4·4%).

5β-*Benzyloxy*-7aβ-*methyl*-trans-*perhydroindan*-1-*one* (28; R = CH_2Ph).—The crude hydroxy-acetal mixture just described (144 mg.) was oxidised with chromic oxide in pyridine to the crude oily keto-acetal (98 mg.), $\nu_{max.}$ 1710 cm.$^{-1}$. Reduction with ethanolic sodium borohydride gave an oil (108 mg.) showing no i.r. absorption near 6 μm. The oil (178 mg.) was benzylated with benzyl chloride and potassium hydroxide in toluene, and the product was hydrolysed with aqueous methanolic sulphuric acid to remove the acetal residue. The resulting benzyloxy-ketone was isolated as the oxime (39 mg.), m.p. 123—125°, undepressed on admixture with material prepared as described later (Found: C, 75·0; H, 8·55; N, 5·4. Calc. for $C_{17}H_{23}NO_2$: C, 74·7; H, 8·5; N, 5·1%).

A sample (300 mg.) of the oxime was heated under reflux for 3 hr. with N-sulphuric acid (12 c.c.) and ethanol (48 c.c.); after removal of the ethanol under reduced pressure and dilution with water the oily benzyloxy-ketone (269 mg.), $\nu_{max.}$ 1734 cm.$^{-1}$, was isolated with ether. The benzyl group was removed by hydrogenolysis with 5% palladised charcoal, giving the hydroxy-ketone (28; R = H) as an oil (175 mg.), $\nu_{max.}$ 1735 cm.$^{-1}$. The p-*nitrobenzoate* separated from ether–light petroleum as needles, m.p. 108—111°, $\nu_{max.}$ (KCl) 1745 and 1718 cm.$^{-1}$ (Found: C, 64·5; H, 5·95; N, 4·65. $C_{17}H_{19}NO_5$ requires C, 64·3; H, 6·0; N, 4·4%).

2-*Carboxy*-2-*methylcyclohex*-4-*eneacetic Acid* (24).—The β-diketone (17) (2·46 g.) was dissolved in an ice-cold solution of sodium hydroxide (12 g.) and bromine (2·75 c.c.) in water (100 c.c.) and the solution was kept at 18° for 0·75 hr. After removal of bromoform with ether and of the excess of hypobromite by sodium bisulphite, addition of hydrochloric acid to the cooled (5°) solution gave the *dibasic acid* (1·91 g.), which formed prisms, m.p. 208—209° (from ethanol–ethyl acetate) (Found: C, 60·65; H, 7·15. $C_{10}H_{14}O_4$ requires C, 60·6; H, 7·1%). The oily dimethyl ester (1·67 g.), prepared with diazomethane, was heated under reflux with aqueous methanolic 0·4N-sodium hydroxide (18·5 c.c.) for 3 hr. The cooled solution was diluted with water and extracted with ether; acidification of the aqueous phase and extraction with ether gave the *monomethyl ester* (1·1 g.), m.p. 89—90° (from light petroleum), $\nu_{max.}$ 1724 and 1704 cm.$^{-1}$ (Found: C, 62·45; H, 7·5. $C_{11}H_{16}O_4$ requires C, 62·25; H, 7·6%). This ester is the one containing the tertiary methoxycarbonyl group.

2-*Carboxy*-2-*methylcyclohex*-4-*enepropionic Acid*.—The foregoing monomethyl ester (5·91 g.), benzene (20 c.c.), thionyl chloride (8·5 c.c.), and a few drops of pyridine were

kept together at 18° for 1 hr. and then at 40° for 10 min.; solvents and reagents were then removed under reduced pressure and the residual acid chloride was treated with more benzene, which was evaporated off, and the acid chloride was then dissolved in ether (40 c.c.). The solution was filtered and the filtrate was added during 30 min. to a stirred and cooled (5°) solution of diazomethane (3 equiv.) in ether; after a further 30 min. the solution was evaporated under reduced pressure. The residual *diazo-ketone* (6·32 g.) separated from benzene–light petroleum as pale yellow prisms, m.p. 57—58° (Found: C, 60·7; H, 6·55; N, 11·65. $C_{12}H_{16}N_2O_3$ requires C, 61·0; H, 6·8; N, 11·9%).

The crude diazo-ketone (6·32 g.) was rearranged in methanol (100 c.c.) at 60° by the addition of dry silver oxide (1·7 g.) during 1·5 hr., followed by heating under reflux for 15 min. Filtration, evaporation, and chromatography from benzene and benzene–ether mixtures on silica gel (250 g.) gave the oily dimethyl ester (4·13 g.) $\nu_{max.}$ 1730 and 1653 cm.$^{-1}$. Hydrolysis of a portion with hot 20%aqueous ethanolic potassium hydroxide gave the *dibasic acid* as small prisms (from ethyl acetate–light petroleum), m.p. 142—143° (Found: C, 61·95; H, 7·5. $C_{11}H_{16}O_4$ requires C, 62·25; H, 7·6%).

Dieckmann Cyclisation of the Dimethyl Ester of 2-*Carboxy*-2-*methylcyclohex*-4-*enepropionic Acid*.—The crude dimethyl ester (3·9 g.) and dry sodium methoxide [from sodium (0·8 g.)] were stirred and refluxed together in benzene (100 c.c.) under nitrogen for 7 hr., and then kept overnight at 18°. The mixture was washed successively with dilute hydrochloric acid, aqueous sodium carbonate, and water, and then dried and evaporated. The crude β-*keto-ester* (3·1 g.) crystallised from light petroleum had m.p. 82—83°, $\nu_{max.}$ (KCl) 1757, 1721, and 1640 cm.$^{-1}$ (Found: C, 69·05; H, 7·6. $C_{12}H_{16}O_3$ requires C, 69·2; H, 7·7%).

The crude β-keto-ester (3·1 g.) was boiled under nitrogen for 1 hr. with glacial acetic acid (100 c.c.), concentrated hydrochloric acid (50 c.c.), and water (10 c.c.), after which solvents were removed at 40°. The residue was dissolved in ether, and the solution was washed with dilute aqueous sodium hydroxide and with water. Evaporation and distillation gave the tetrahydroindanone (22) as an oil (1·71 g.), b.p. 49—54°/0·65 mm., $\nu_{max.}$ 1742 and 1640 cm.$^{-1}$. The 2,4-dinitrophenylhydrazone, m.p. 197—198°, was identical with material prepared previously (Found: C, 57·8; H, 5·45; N, 16·7. Calc. for $C_{16}H_{18}N_4O_4$: C, 58·2; H, 5·5; N, 17·0%).

6-*Benzyloxy*-8a-*methyldecalin*-1-*one* (26; R = CH_2Ph).—A solution of the 1-monoethylene acetal (10 g.) of the diketone (25) in ether (200 c.c.), methanol (600 c.c.), and liquid ammonia (1 l.) was cooled (−70°) and stirred while sodium (100 g.) was added in small pieces during 4·5 hr. After a further 1 hr., ammonium chloride (160 g.) was added, the ammonia was allowed to evaporate, and after the addition of water the product was isolated with ether. The *hydroxy-acetal* (9·6 g.) separated from ether–light petroleum as needles (5·1 g.), m.p. 90—92° (Found: C, 69·05; H, 9·7. $C_{13}H_{22}O_3$ requires C, 69·0; H, 9·8%). The 3,5-*dinitrobenzoate* (from acetone) had m.p. 154—155° (Found: C, 57·2; H, 5·75; N, 6·85. $C_{20}H_{24}N_2O_8$ requires C, 57·1; H, 5·75; N, 6·7%).

A portion (18 g.) of the hydroxy-acetal was benzylated with benzyl chloride (120 c.c.) and powdered potassium hydroxide (90 g.) in boiling toluene (600 c.c.) with *vigorous* stirring during 16 hr. The *benzyl ether* formed needles (15 g.), m.p. 59—61° (from light petroleum) (Found: C, 76·05; H, 8·85. $C_{20}H_{28}O_3$ requires C, 75·9; H, 8·9%). Hydrolysis of a portion (1·94 g.) with aqueous methanolic sulphuric acid gave the benzyloxy-ketone (26; R = CH_2Ph) (1·63 g.), $\nu_{max.}$ 1702 cm.$^{-1}$. The *furfurylidene derivative* had m.p. 132—134° (from ethanol) (Found: C, 79·2; H, 7·25. $C_{23}H_{26}O_3$ requires C, 78·8; H, 7·5%).

5-*Benzyloxy*-2-*carboxy*-2-*methylcyclohexanepropionic Acid* (27).—The foregoing furfurylidene derivative (500 mg.) and methanol (180 c.c.) containing sodium methoxide [from sodium (2 g.)] and 50% hydrogen peroxide (20 c.c.) were stirred together vigorously for 24 hr.; more hydrogen peroxide (20 c.c.) and methanol (20 c.c.) were added after 18 hr. The methanol was removed under reduced pressure, and after dilution of the solution with water the product was isolated with ether, and separated into neutral (197 mg.) and acidic (220 mg.) fractions. The neutral fraction consisted of starting material; the acidic material separated from benzene–ethyl acetate giving the *dibasic acid*, m.p. 165—167° (Found: C, 67·8; H, 7·4. $C_{18}H_{24}O_5$ requires C, 67·5; H, 7·55%).

Dieckmann Cyclisation of the Dimethyl Ester of the Acid (27).—Dry potassium t-butoxide [from potassium (3 g.)] and dimethyl ester, made from the dibasic acid (0·68 g.) and diazomethane, were refluxed together in benzene (500 c.c.) with stirring for 4 hr., and then kept for 24 hr. at room temperature. After the addition of dilute sulphuric acid with shaking, the benzene layer was separated, washed with water, dried, and evaporated to an oil (0·6 g.). It was heated under reflux for 1 hr. with toluene-*p*-sulphonic acid (3 g.) in acetic acid (30 c.c.) and water (6 c.c.), after which the solvent was removed under reduced pressure at 40°, and the residue was treated with water and ether. Evaporation of the washed ether layer gave the benzyloxyperhydroindanone (28; R = CH_2Ph) as an oil (0·45 g.). A portion (168 mg.) was converted into the *oxime* (110 mg.), needles (from light petroleum), m.p. 125—126° (Found: C, 75·0; H, 8·3; N, 5·0. $C_{17}H_{23}NO_2$ requires C, 74·7; H, 8·5; N, 5·1%).

8a-*Methyl*-$\Delta^{4a,5}$-*octalin*-1-*ol* (29).—Reduction of the dione (25) (34 g.) with sodium borohydride (2·24 g.) in ethanol (135 c.c.) and propan-2-ol (135 c.c.) at 0° for 1 hr. gave 1-hydroxy-8a-methyl-$\Delta^{4a,5}$-octalin-6-one; acetylation gave the *acetate* (29·1 g.), m.p. 90—91° (from light petroleum) (Found: C, 70·4; H, 8·2. $C_{13}H_{18}O_3$ requires C, 70·2; H, 8·2%). The corresponding *benzoate* had m.p. 93—94° (from methanol) (Found: C, 76·1; H, 6·95. $C_{18}H_{20}O_3$ requires C, 76·0; H, 7·1%).

The acetoxy-ketone (28 g.) and sodium borohydride (4 g.) were kept together in ethanol at 18° for 2 hr.; the solution was then evaporated under reduced pressure, water (100 c.c.) was added, and the product was isolated with ether. It formed an oil (27·4 g.), showing strong i.r. absorption near 3300 cm.$^{-1}$, but none near 1660 cm.$^{-1}$. Its solution in dry ether (200 c.c.) and pure thionyl chloride (15 c.c.) were kept together at 18° for 1 hr., after which the solution was evaporated under reduced pressure. A solution of the residue in ether (100 c.c.) was added dropwise to a stirred suspension of lithium aluminium hydride (7 g.) in ether (500 c.c.) at 0°; the solution was then heated under reflux for 18 hr. The stirred and cooled solution (0°) was treated cautiously with ethyl acetate and then with dilute sulphuric acid (200 c.c.), and the product was isolated with ether in the usual way. Distillation at 85—90°/1 mm. gave crude 8aβ-methyl-$\Delta^{4a,5}$-octalin-1β-ol (29) (12 g.) con-

taining *ca.* 10% (t.l.c.) of a hydroxy-diene (u.v. and i.r. data). The 3,5-*dinitrobenzoate* of the octalinol (29) had m.p. 139—141° (Found: C, 60·1; H, 5·4; N, 7·9. $C_{18}H_{20}N_2O_6$ requires C, 60·0; H, 5·6; N, 7·8%).

8a-*Methyl*-$\Delta^{4a,5}$-*octalin*-1-*one Ethylene Acetal* (31).—A solution of chromic oxide (6·68 g.), and concentrated sulphuric acid (5·75 c.c.) in water (final volume 25 c.c.) was added during 10 min. to a stirred solution of the octalinol (29) (11·3 g.) in acetone (100 c.c.) at 0°. Water (200 c.c.) was then added, and the product was isolated with ether in the usual way. The crude ketone (30) formed an oil (9·5 g.), $\nu_{max.}$ 1705 cm.$^{-1}$. The *oxime* had m.p. 103·5—104·5° (Found: C, 73·5; H, 9·55; N, 8·1. $C_{11}H_{17}NO$ requires C, 73·7; H, 9·6; N, 7·8%); the 2,4-*dinitrophenylhydrazone* had m.p. 139—140° (Found: C, 59·7; H, 5·5; N, 16·55. $C_{17}H_{20}N_4O_4$ requires C, 59·3; H, 5·8; N, 16·3%).

The ketone (30) (8·9 g.), ethylene glycol (5 c.c.), toluene-*p*-sulphonic acid (0·5 g.), and benzene (200 c.c.) were heated together under reflux with continuous removal of water for 4 hr. The cooled solution was then washed with water, the benzene was evaporated off, and a solution of the residue in light petroleum (b.p. 60—80°) was passed through alumina (grade I; 50 g.), and evaporated. The crude acetal (31) (8·1 g.) showed no ketonic absorption in the 6 μm. region.

Hydroboration of the Acetal (31).—The acetal (2·4 g.) was kept at 20° for 2 hr. in tetrahydrofuran (20 c.c.) containing a slight excess of diborane; the solvent was then removed under reduced pressure and the residue was kept at 30° for 0·5 hr. with aqueous 2N-sodium hydroxide (10 c.c.) and 40% hydrogen peroxide (10 c.c.). Extraction with chloroform gave a gum (2·25 g.) which was chromatographed on alumina (grade II; 75 g.) with benzene as eluant; the fractions were examined by t.l.c. (Kieselgel G; ether). After an initial fraction (250 mg.) had been discarded, early fractions (760 mg.) contained largely material with R_F 0·9. Later fractions (650 mg.) contained material of R_F 0·75 together with the less strongly adsorbed material. A portion (220 mg.) of the material R_F 0·9 was heated under reflux with 50% ethanol–water (10 c.c.) and 2N-sulphuric acid (0·5 c.c.) for 1 hr.; the ethanol was then removed and the product was isolated with ether. Crystallisation from light petroleum (b.p. 60—80°) gave 5β-*hydroxy*-8aβ-*methyl*-cis-*decalin*-1-*one* (108 mg.), m.p. 65—66·5° (Found: C, 72·9; H, 10·0. $C_{11}H_{18}O_2$ requires C, 72·5; H, 10·0%).

The cis-*Keto-acetal* (33) *and Its Isomerisation*.—The hydroxy-acetal (32) of R_F 0·9 (605 mg.) was added to a stirred solution of chromic oxide (2 g.) in pyridine (20 c.c.) at 20°. After 18 hr. the solution was diluted with water and the product was isolated with ether. The keto-acetal (33) formed an oil (543 mg.), $\nu_{max.}$ 1710 and 962 cm.$^{-1}$. A portion (443 mg.) was heated under reflux for 4 hr. with sodium ethoxide [from sodium (0·35 g.)] in ethanol (15 c.c.), after which the ethanol was removed at 20° under reduced pressure, and the residue was diluted with water (30 c.c.). The product (439 mg.) was isolated with ether, and showed $\nu_{max.}$ 1710 and 926 cm.$^{-1}$. The new keto-acetal was reduced with sodium borohydride (100 mg.) in ethanol (20 c.c.) for 4 hr. at 18°; work-up in the usual way gave a hydroxy-acetal mixture (390 mg.). A portion (260 mg.) was refluxed with ethanol (5 c.c.), water (3 c.c.) and 2N-sulphuric acid (0·2 c.c.) for 0·5 hr., after which the product was isolated in the usual way; it was an oil (220 mg.). Chromatography on alumina (grade II; 20 g.) and elution, first with benzene, then with benzene–ether, gave a fraction (110 mg.) containing mainly a compound with R_F 0·75 (Kieselgel G; chloroform). Crystallisation from light petroleum (b.p. 60—80°) gave 5β-*hydroxy*-8aβ-*methyl*-trans-*decalin*-1-*one* (36), m.p. 83—84° (Found: C, 72·45; H, 9·75. $C_{11}H_{18}O_2$ requires C, 72·5; H, 10·0%). The *furfurylidene derivative* had m.p. 167—169° (Found: C, 73·6; H, 7·6. $C_{16}H_{20}O_3$ requires C, 73·8; H, 7·7%), and the *acetate* of the furfurylidene derivative had m.p. 121—122° (Found: C, 71·5; H, 7·2. $C_{18}H_{22}O_4$ requires C, 71·5; H, 7·3%). Ozonolysis of the latter, followed by work-up with hydrogen peroxide and acetic acid, and subsequent hydrolysis with alkali, afforded the δ-*lactone* of *cis*-2-carboxy-*cis*-6-hydroxy-*trans*-2-methylcyclohexanepropionic acid (from ethyl acetate–light petroleum), m.p. 150—152° (Found: C, 62·35; H, 7·55. $C_{11}H_{16}O_4$ requires C, 62·25; H, 7·6%).

Preparation of the Hydroxy-decalone (36) *from Hydroxy-acetal* (34).—Fractions (450 mg.) from the hydroboration experiment containing both the hydroxy-acetal (32), R_F 0·9, and the hydroxy-acetal (34), R_F 0·75, were kept for 18 hr. at 20° with chromic oxide (2·1 g.) in pyridine (20 c.c.). Work-up in the usual way afforded a mixture of keto-acetals, $\nu_{max.}$ 1710, 962, and 926 cm.$^{-1}$. It was kept in ethanol (10 c.c.) containing sodium borohydride (100 mg.) at 18° for 4 hr., and the product (367 mg.), isolated in the usual way, was hydrolysed with aqueous ethanolic sulphuric acid to a mixture of hydroxy-ketones. Chromatography on alumina (grade II) gave the hydroxy-*trans*-decalone (36) (100 mg.) which crystallised, giving pure material (47 mg.), m.p. 82—84°.

Conversion of the Hydroxy-ketone (36) *into* 8a-*Methyl*-trans-*decalin*-1-*one*.—Reaction of the hydroxy-ketone with benzoyl chloride in pyridine gave the *benzoate*, m.p. 136° [from light petroleum (b.p. 80—100°)] (Found: C, 75·5; H, 7·8. $C_{18}H_{22}O_3$ requires C, 75·5; H, 7·7%).

It was heated at 300°/750 mm. for 15 min., and then distilled. The distillate was dissolved in ether and freed from benzoic acid by washing with sodium hydrogen carbonate solution. The product (100 mg.) was then isolated by removal of solvent and distillation under reduced pressure, leaving behind unchanged benzoate. After hydrogenation with 10% palladised charcoal in ethyl acetate, the saturated product was kept for 1 hr. in ethanol (2 c.c.) with furfuraldehyde (0·3 c.c.) and 15% aqueous sodium hydroxide (1 c.c.). The furfurylidene derivative of 8a-methyl-*trans*-decalin-1-one (78 mg.) had m.p. 109—110·5° (lit.,[18] 110°) (Found: C, 78·25; H, 8·25. Calc. for $C_{16}H_{20}O_2$: C, 78·65; H, 8·25%).

8β-*Hydroxy*-4aβ-*methyl*-trans-*decalin*-2-*one* (41; R = H).—Starting material for this preparation was an 80% pure (g.l.c.) sample (4 g.) of the equilibrium mixture[16] of the *trans*- (39) and *cis*-keto-acetals (3 : 1). To its stirred solution in ethanol (20 c.c.) a solution of sodium borohydride (900 mg.) in ethanol (20 c.c.) and propan-2-ol (20 c.c.) was added; stirring was continued at 18° for 3 hr., after which glacial acetic acid (8 c.c.) was added, and the solvents were removed under reduced pressure. The product was then isolated with ether, and chromatographed on neutral alumina (grade II), with ether–benzene (1 : 4) as eluant. The fraction (2·10 g.) containing material R_F 0·7 (Kieselgel G; 4% ethanol–benzene) crystallised from ether–light petroleum (b.p. 40—60°) giving the *hydroxy-acetal* (40) (1·85 g.) m.p. 95·5° (Found: C, 68·75; H, 9·45. $C_{13}H_{22}O_2$ requires C, 69·0; H, 9·8%).

[18] W. S. Johnson, B. Bannister, and R. Pappo, *J. Amer. Chem. Soc.*, 1956, **78**, 6331.

A portion (700 mg.) was hydrolysed by heating under reflux with N-hydrochloric acid (18 c.c.) in acetone (30 c.c.) during 1 hr. After removal of the solvent under reduced pressure, the product was isolated with ether. Crystallisation from ether–light petroleum (b.p. 40—60°) gave the *hydroxy-ketone* (41; R = H) (550 mg.), m.p. 79·5° (Found: C, 72·8; H, 9·75. $C_{11}H_{18}O_2$ requires C, 72·5; H, 10·0%). The acetate (41; R = Ac) had $\nu_{max.}$ (film) 1740, 1705, and 1250 cm.$^{-1}$.

8β-*Acetoxy*-4aβ-*methyl*-trans-Δ^3-*octalin*-2-*one* (45).—To the keto-acetate (41; R = Ac) (1·5 g.) in glacial acetic acid (55 c.c.) a solution of bromine (1·17 g.) in glacial acetic acid (13 c.c.) containing hydrogen bromide (0·04 g.) was added during 10 min. at 18° with stirring. After a further 15 min., ether (50 c.c.) was added, followed by (care!) aqueous 2N-sodium hydrogen carbonate (1·25 l.). Isolation with ether, and crystallisation of the product from benzene–light petroleum (b.p. 40—60°) gave the *bromo-ketone* (42) (1·8 g.), m.p. 156° (Found: C, 51·55; H, 6·25; Br, 26·1. $C_{13}H_{19}BrO_3$ requires C, 51·5; H, 6·3; Br, 26·4%), $\nu_{max.}$ (film) 1740, 1720, and 1240 cm.$^{-1}$, τ 5·2 (C*H*Br, X proton of an ABX system, $J_{AX} + J_{BX} = 19$ Hz).

A portion (1·72 g.) was boiled and stirred with lithium carbonate (3·8 g.) in dimethylformamide (40 c.c.) for 2 hr. The cooled solution was added to 2N-hydrochloric acid (60 c.c.), and the product was isolated with ether and chromatographed on silica gel (110 g.) from benzene, with elution first with benzene, and then with benzene–ether (1 : 6). The fraction (910 mg.) with R_F 0·7 (Kieselgel G; 7% ethanol–benzene) had $\lambda_{max.}$ 228 nm. (ε 11,000); it was the enone (45), τ 3·3 and 4·25 (each d, J 10 Hz, vinyl H).

To this material (800 mg.) in methanol (7·1 c.c.) at 0° were added 4N-sodium hydroxide (0·45 c.c.) and 20% hydrogen peroxide (0·61 c.c.), and the solution was stirred while its temperature rose to 20° (0·5 hr.). Dilution with water and isolation with chloroform gave the epoxide(s) (44) as an oil (780 mg.), $\nu_{max.}$ (film) 1740, 1710, and 1240 cm.$^{-1}$, ε_{228} <400. After chromatography from benzene on neutral alumina (grade III; 80 g.), homogeneous material (690 mg.) was obtained; it had R_F 0·7 (Kieselgel G; 7% ethanol–benzene).

2,7-*Dihydroxy*-3a-*methylperhydroindane*-2-*carboxylic Acid* (43).—The purified epoxy-ketone material (44) (446 mg.), 6N-sodium hydroxide (27·5 c.c.), and dioxan (2·5 c.c.) were boiled together under reflux with stirring for 2 hr. The cooled solution was extracted with ether to remove neutral material, and then acidified with 8N-hydrochloric acid. Continuous extraction with ether, and crystallisation from benzene–light petroleum (b.p. 40—60°) gave the *dihydroxy-acid* (43) as needles (285 mg.), m.p. 183—184° (Found: C, 62·05; H, 8·15. $C_{11}H_{18}O_4$ requires C, 61·7; H, 8·5%).

7-*Hydroxy*-3a-*methylperhydroindan*-2-*one* (46).—The hydroxy-acid (43) (90 mg.) and lead tetra-acetate (500 mg.) were stirred together in glacial acetic acid (15 c.c.) for 44 hr.; ethylene glycol (1 c.c.) was then added, and after 30 min. the acetic acid was removed under reduced pressure. The product was isolated with ether, and chromatographed on neutral alumina from benzene. Elution with ether–benzene (1 : 9) gave a homogeneous fraction (58 mg.), $\nu_{max.}$ (film) 3500 and 1735 cm.$^{-1}$, consisting of the hydroxy-ketone (46). The p-*nitrobenzoate* formed plates (54 mg.) from ethyl acetate, m.p. 123—124° (Found: C, 64·3; H, 6·3; N, 4·5. $C_{17}H_{19}NO_5$ requires C, 64·3; H, 6·0; N, 4·4%).

5-*Acetoxy*-8a-*methyl*-Δ^2-*octalin*-1-*one* (47).—The epoxy-ketonic material (44) (410 mg.), hydrazine hydrate (230 mg.), and glacial acetic acid (20 mg.) were stirred together in ethanol (3·2 c.c.) for 15 min.; the solution was then poured into water (50 c.c.), and the product was isolated with chloroform. It appeared homogeneous on t.l.c. and had $\nu_{max.}$ (film) 3500, 1740, and 1650 cm.$^{-1}$. Its solution in glacial acetic acid (6·5 c.c.) was stirred with chromic oxide (200 mg.) in water (0·15 c.c.) for 18 hr. at 18°, after which methanol (6 c.c.) and then water (50 c.c.) were added. The product was isolated with ether, and chromatographed on silica gel giving an oil (47) (300 mg.) $\lambda_{max.}$ 225 nm. (ε 9000), τ 3·03 and 3·98 (each 1 H, each d, J 11 Hz, vinyl H).

The *epoxide* (48), prepared in the usual way (yield 80%), separated from light petroleum (b.p. 40—60°), as needles, m.p. 108—109°, $\nu_{max.}$ (KCl) 1740 and 1710 cm.$^{-1}$ (Found: C, 65·8; H, 7·35. $C_{13}H_{18}O_4$ requires C, 65·5; H, 7·6%).

Hydrogenation of a sample (300 mg.) of the αβ-unsaturated ketone (47) with 5% palladised charcoal in ethanol, followed by hydrolysis of the product with cold aqueous methanolic N-potassium hydroxide gave the hydroxy-ketone (36) (190 mg.), m.p. 86—87°, further characterised as the furfurylidene derivative, m.p. 166—168°.

1,4-*Dihydroxy*-7a-*methylperhydroindane*-1-*carboxylic Acid* (50).—The epoxide (48) (105 mg.) and 6N-sodium hydroxide were stirred and boiled together with dioxan (0·6 c.c.) for 2 hr.; water was then added, and neutral material was removed by extraction with ether. Acidification and extraction with ether gave the *hydroxy-acid* (50), which separated from ethyl acetate–light petroleum (b.p. 40—60°) as needles (77 mg.), m.p. 200° (Found: C, 61·3; H, 8·4. $C_{11}H_{18}O_4$ requires C, 61·7; H, 8·5%).

4-*Hydroxy*-7a-*methylperhydroindan*-1-*one* (49).—Reaction of the hydroxy-acid (50) (70 mg.) with lead tetra-acetate in acetic acid in the usual way gave the hydroxy-ketone (49) as an oil (50 mg.), $\nu_{max.}$ (film) 3500 and 1735 cm.$^{-1}$. The 3,5-*dinitrobenzoate* formed plates (90 mg.) from ethanol, m.p. 134—135° (Found: C, 56·7; H, 5·1; N, 7·7. $C_{17}H_{18}N_2O_7$ requires C, 56·35; H, 5·0; N, 7·7%). The semicarbazone of the 3,5-dinitrobenzoate had m.p. 232—234° (lit.,[14] 229—231°) (Found: C, 51·9; H, 5·1; N, 16·4. Calc. for $C_{18}H_{21}N_5O_7$: C, 51·5; H, 5·0; N, 16·7%).

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