Steroid Analogues. Part 2.[1] Synthesis of Unsymmetrical Bi(cycloalkylidene)s *via vic*-Dinitro-compounds

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The light-catalysed reaction of 4,4-dinitrocyclohexanol (6) with the lithium salts of 4-substituted 1-nitrocyclohexanes [4-OBz (4), 4-CH_2CO_2Me (12), 4-CH_2COMe (15), and 4-H (11)] gave 4'-substituted 4-hydroxy-1,1'-dinitro-1,1'-bicyclohexyls (16). Irradiation of the latter in the presence of sodium sulphide in dimethylformamide gave 4'-substituted 4-hydroxy-1,1'-bi(cyclohexylidene)s (17)—(21) in overall yields of 29—70%. Condensation of (±)-6β-methyl-3,3-dinitro-*trans*-bicyclo[4.3.0]nonan-7β-ol (31) with the lithium salt of 4-benzoyloxy-1-nitrocyclohexane (4) gave in 12% yield a 1 : 1 mixture of the epimeric (±)-3ξ,17β-dihydroxy-6,7-dinor-5,8-seco-estr-9-enes (33).

In the preceding paper [1] we describe the preparation of bicyclic intermediates that could serve as the precursors of rings C and D in our projected series of 6,7-dinor-5,8-seco-Δ^9-steroids. In this and subsequent papers [2-4] we describe the various methods used to attach a ring A synthon to these intermediates.

Kornblum and his co-workers [5-7] recently described a synthesis of cycloalkylidenecycloalkanes by a two-stage process involving coupling of nitro-compounds; the light-catalysed condensation of a *gem*-dinitroalkane with the lithium salt of a nitrocycloalkane in dimethyl sulphoxide gave a *vic*-dinitro-compound that, on irradiation in dimethylformamide in the presence of sodium sulphide, yielded the desired olefin in high yield. The first stage can also be carried out in dimethylformamide,[8] making possible a 'one-pot' process. We planned first to confirm that this method was compatible with the presence of oxygen-containing functional groups by the synthesis of a number of substituted bi(cyclohexylidene)s that were of interest to us in their own right, and then to extend it to the preparation of the desired tricyclic compounds.

A mixture of the lithium salt of 4-nitrocyclohexyl benzoate (4), prepared by oxidation of the corresponding oxime (2) with trifluoroperacetic acid,[9] and 1,1-dinitrocyclohexane was irradiated in dry dimethyl sulphoxide to give, in 86% yield, a mixture of the epimeric *vic*-dinitro-compounds (8). Crystallisation from hot acetone afforded a single pure isomer (14%) which, on irradiation in the presence of sodium sulphide in dimethylformamide, yielded a mixture of 4-hydroxy-1,1'-bi(cyclohexylidene) (17) (71%) and the corresponding benzoate (9) (9%).

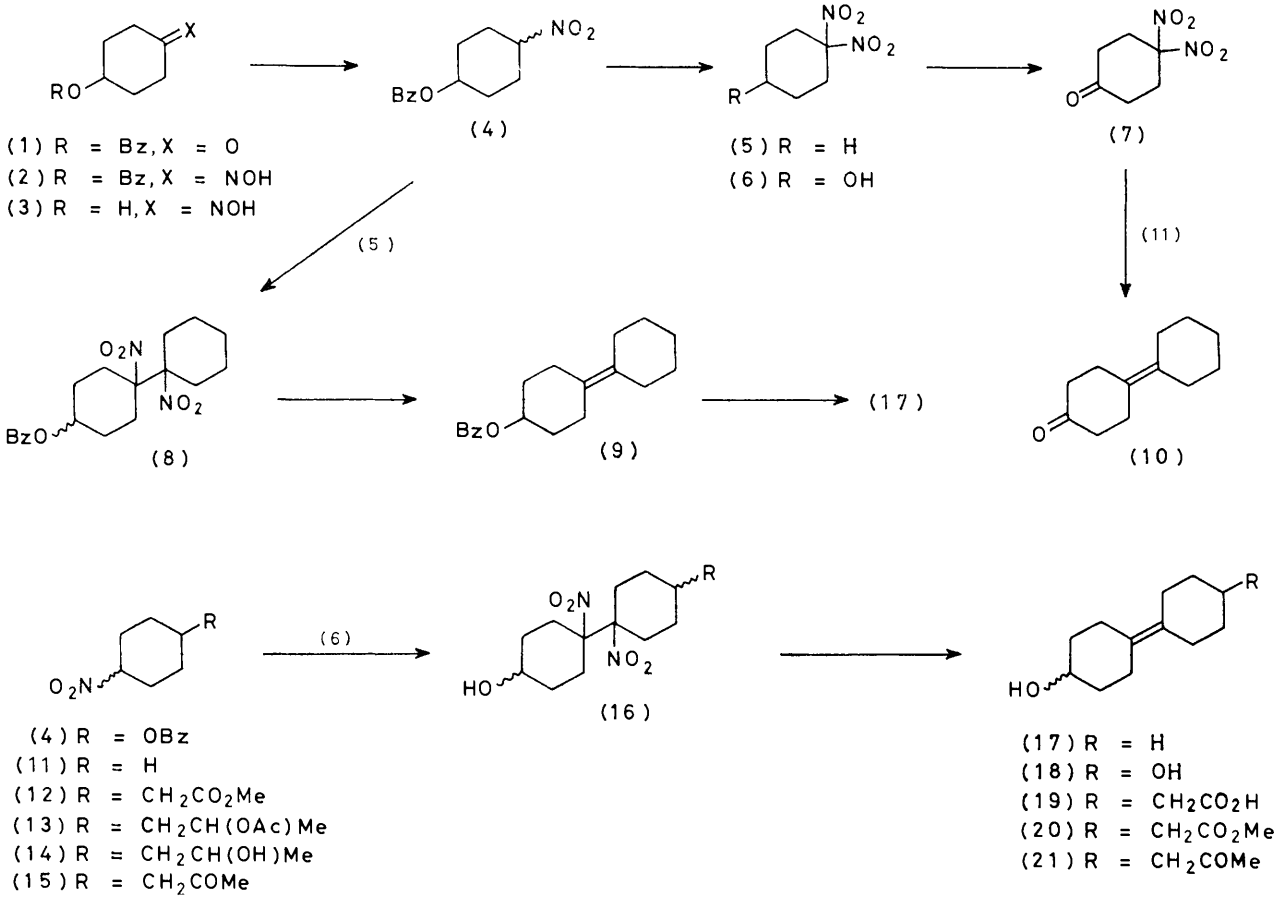
Hydrolysis of 4-nitrocyclohexyl benzoate (4) with 2 equiv. of sodium hydroxide, followed by treatment with silver nitrate and sodium nitrite,[10] gave 4,4-dinitrocyclohexanol (6) (42%), which was oxidised to the ketone (7) with Jones reagent. Irradiation of a mixture of (6) and the lithium salt of nitrocyclohexane in dimethyl sulphoxide gave the dinitro-compound (16; R = H) in 24% yield after recrystallisation of the total product. A similar condensation was conducted in dimethylformamide [8] and the *vic*-dinitro-compound (16; R = H) was reduced directly to the olefin (17) in 70% overall yield by addition of sodium sulphide to the reaction mixture and further irradiation.

Condensation of 4,4-dinitrocyclohexanone (7) with the lithium salt of nitrocyclohexane in dimethylformamide and direct reduction of the intermediate, as above, gave only 5% of the desired 1,1'-bi(cyclohexyliden)-4-one (10). We believe that the poor yield was due to protonation of the nitro-salt by the enol form of the ketone.

This coupling process was next used to prepare bi(cyclohexylidene)s bearing substituents in each ring. A solution of 4,4-dinitrocyclohexanol (6) and 4-nitrocyclohexyl benzoate (4) in dimethyl sulphoxide was treated with n-butyl-lithium (2 equiv.) and irradiated in the

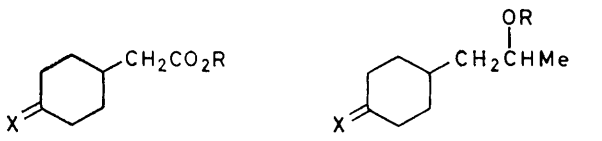
[1] Part 1, D. J. Humphreys, C. E. Newall, H. A. Paskins, and G. H. Phillipps, preceding paper.
[2] D. J. Humphreys, P. M. Lawrence, C. E. Newall, G. H. Phillipps, and P. A. Wall, following paper.
[3] D. J. Humphreys and C. E. Newall, *J.C.S. Perkin I*, 1978, 33.
[4] D. J. Humphreys, C. E. Newall, G. H. Phillipps, and G. A. Smith, *J.C.S. Perkin I*, 1978, 45.
[5] N. Kornblum, S. F. Boyd, H. W. Pinnick, and R. G. Smith, *J. Amer. Chem. Soc.*, 1971, **93**, 4316.
[6] N. Kornblum, S. D. Boyd, and F. W. Stuchal, *J. Amer. Chem. Soc.*, 1970, **92**, 5787.
[7] N. Kornblum and S. D. Boyd, *J. Amer. Chem. Soc.*, 1970, **92**, 5788.
[8] G. A. Russell, R. K. Norris, and E. J. Panek, *J. Amer. Chem. Soc.*, 1971, **93**, 5839.
[9] W. D. Emmons and A. S. Pagano, *J. Amer. Chem. Soc.*, 1955, **77**, 4557.
[10] R. B. Kaplan and H. Schechter, *J. Amer. Chem. Soc.*, 1961, **83**, 3535.

usual way. Reduction of the total crude product with sodium sulphide under irradiation gave 4,4'-dihydroxy-1,1'-bi(cyclohexylidene) (18) in 29% yield (purity by g.l.c. 83.5%); comparison with authentic samples [4] of the *cis*- and *trans*-diols (18) showed that this material



was a 1 : 1 mixture of the two isomers. This lack of stereoselectivity is in keeping with Kornblum's evidence [5,7] in favour of a radical-anion mechanism for both coupling and reduction steps.

The synthesis of the bi(cyclohexylidene)s (19) and (21) was next examined; these two compounds can be regarded as bicyclic analogues of an androstane-17-carboxylic acid and a pregnan-20-one, respectively.



(22) X = O, R = H
(23) X = O, R = Me
(24) X = NOH, R = Me
(25) X = O, R = H
(26) X = O, R = Ac
(27) X = NOH, R = Ac

Birch reduction of 4-methoxyphenylacetic acid, followed by hydrolysis and catalytic hydrogenation of the product, gave 4-oxocyclohexylacetic acid [11] (22). The methyl ester (23) was converted into the oxime (24), which was oxidised to methyl 4-nitrocyclohexylacetate (12). A mixture of the ester (12), 4,4-dinitrocyclohexanol (6), and 2 equiv. of lithium methoxide was irradiated in dimethyl sulphoxide. Reduction of the resulting *vic*-dinitro-compound with sodium sulphide in dimethylformamide under irradiation afforded a mixture of the acid (19) (18%) and its methyl ester (20) (30%).

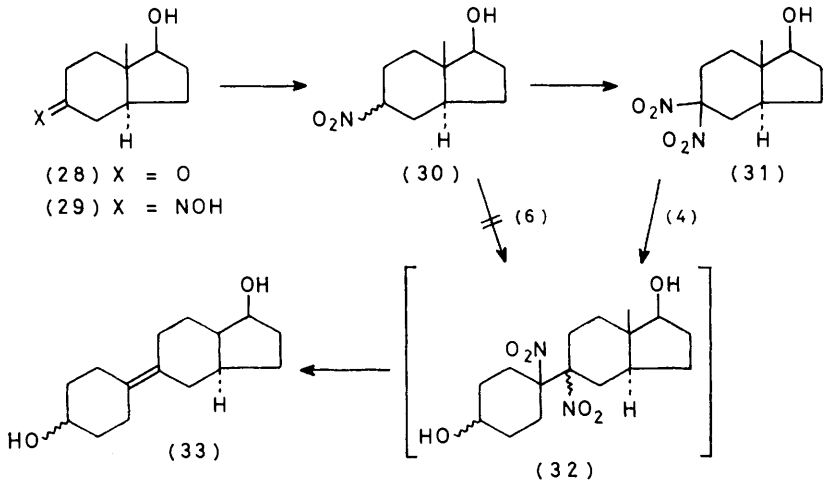
4-Methoxyphenylacetone was converted by successive Birch reduction, acidic hydrolysis, and catalytic hydrogenation into the hydroxy-ketone (25). Acetylation of the latter, followed by reaction with hydroxylamine, furnished the oxime (27), which was oxidised to the nitro-ester (13). Mild acidic hydrolysis of the latter and subsequent oxidation gave 1-acetonyl-4-nitrocyclohexane (15), which was condensed with 4,4-dinitrocyclohexanol (6) in the usual manner to give the desired enone (21) in 57% yield.

Condensations involving bicyclic nitro-compounds met with less success. The hydroxy-ketone (28) [1] was converted into the oxime (29) and thence into the nitro-compound (30). The lithium salt of (30) was irradiated in the presence of 4,4-dinitrocyclohexanol (6) in dimethyl sulphoxide, and the crude product was reduced with sodium sulphide in dimethylformamide under irradiation. The product was a complex mixture in which none of the

[11] H. E. Ungnade and F. V. Morriss, *J. Amer. Chem. Soc.*, 1948, **70**, 1898.

desired olefin (33) was detected; however, a small amount of the hydroxy-ketone (28) was isolated. The transformations leading to the regeneration of this ketone are not clear; it is possible that a salt of the nitro-compound (30) underwent a Nef reaction during isolation. Alternatively, (30) may have been reduced by sodium sulphide in a manner analogous to the recently reported [12] reduction of nitro-alkanes by titanium(II) chloride.

Following this failure, the nitro-compound (30) was converted into the *gem*-dinitro-compound (31). Condensation of the latter with the lithium salt of 4-nitrocyclohexyl benzoate (4) in the usual manner again gave a complex mixture, from which the desired olefin (33) was isolated in 12.5% yield. G.l.c. showed that this material was a 1 : 1 mixture of two components; comparison with authentic (±)-3α,17β-dihydroxy-6,7-dinor-5,8-secoestr-9-ene, prepared by another route,[4] confirmed that the product was a mixture of the 3α- and 3β-epimers of the diol (33).



The overall yield of (33) from the hydroxy-ketone (28) was only 2.3%; thus, Kornblum's coupling procedure was not an attractive proposition for the synthesis of seco-steroids for biological evaluation. Subsequent work was therefore based on other, more efficient methods which were concurrently under investigation in our laboratories.

EXPERIMENTAL

For preamble see preceding paper.[1]

4-(2-Acetoxypropyl)cyclohexanone (26).—A solution of 4-(2-hydroxypropyl)cyclohexanone (25) [2] (25 g, 160 mmol) in anhydrous pyridine (150 ml) and acetic anhydride (151 ml) was set aside at 20 °C for 18 h. The mixture was evaporated and the residue was mixed with toluene then re-evaporated, then partitioned between water and dichloromethane. The organic phase was dried and evaporated to an oil (29.5 g, 93%). A small portion (150 mg) was purified by p.l.c. ($CHCl_3$) to give the *acetoxy-ketone* (26) (104 mg), $\nu_{max.}$ 1 720 (ester) and 1 712 cm^{-1} (C=O), τ 8.77 (3 H, d, *J* 6 Hz, CH_3), 7.95 (3 H, s, $OCOCH_3$), and 4.92 (1 H, m, C*H*OAc) (Found: C, 66.5; H, 9.05. $C_{11}H_{18}O_3$ requires C, 66.6; H, 9.15%). The crude product was sufficiently pure for conversion into the oxime (27).

Preparation of Oximes.—The ketone in ethanol was treated with an excess of hydroxylamine hydrochloride and sodium acetate in water and the mixture was stirred under reflux until the reaction was complete. Dilution of the mixture with water afforded the oxime, which was collected by filtration or extracted into dichloromethane.

4-Benzoyloxycyclohexanone oxime [13] (2) was obtained in 96% yield from 4-benzoyloxycyclohexanone [14] (1); it gave (from aqueous ethanol) crystals, m.p. 99—102°, $\nu_{max.}$ 3 570 and 3 280 (OH) and 1 710 cm^{-1} (ester), τ 4.69 (C*H*O·COPh).

(±)-7β-*Hydroxy*-6β-*methyl*-trans-*bicyclo*[4.3.0]*nonan*-3-*one oxime* (29) was obtained from the hydroxy-ketone (28) [1] as an off-white froth (99%) which, on treatment with ether, yielded off-white prisms (25%). Recrystallisation from ether–methanol (4 : 1) gave a pure sample of a single isomer as prisms, m.p. 160—161°, $\nu_{max.}$ 3 595 (OH) and 1 650w cm^{-1} (C=N), τ 9.22 (3 H, s, CH_3) and 6.5 (1 H, m, C*H*OH) (Found: C, 65.7; H, 9.45; N, 7.3. $C_{10}H_{17}NO_2$ requires C, 65.55; H, 9.35; N, 7.65%). The mother liquors were combined and evaporated to give crude oxime which was suitable for conversion into the nitro-compound (30).

4-Methoxycarbonylmethylcyclohexanone oxime (24) was obtained in 95% yield from methyl (4-oxocyclohexyl)-acetate (23) as a yellow oil, $\nu_{max.}$ 3 590 and 3 285 (OH), 1 728 (ester), and 1 660w cm^{-1} (C=N), τ 6.31 (CO_2CH_3) (Found: C, 58.2; H, 8.2; N, 7.2. $C_9H_{15}NO_3$ requires C, 58.35; H, 8.15; N, 7.55%).

4-(2-Acetoxypropyl)cyclohexanone oxime (27) was obtained in quantitative yield from the ketone (26) as an oil. A small portion (200 mg) was subjected to p.l.c. to give the pure oxime (27) (140 mg), $\nu_{max.}$ 3 595 (OH), 1 720 (ester), and 1 660w cm^{-1} (C=N), τ 8.80 (3 H, d, *J* 6 Hz, CH_3), 7.98 (3 H, s, $OCOCH_3$), and 4.95 (1 H, m, C*H*OAc) (Found: C, 61.9; H, 8.8; N, 6.1. $C_{11}H_{19}NO_3$ requires C, 61.95; H, 9.0; N, 6.6%). The crude product was sufficiently pure for conversion into the nitro-compound (13).

4-Hydroxycyclohexanone oxime (3). A solution of 4-benzoyloxycyclohexanone oxime (2) (500 mg, 2.14 mmol) in ethanol (15 ml) and water (30 ml) was heated under reflux for 30 min with aqueous 2N-sodium hydroxide

[12] J. E. McMurry and J. Melton, *J. Amer. Chem. Soc.*, 1971, **93**, 5309.

[13] A. Mooradian, U.S.P. 3 558 667 (*Chem. Abs.*, 1971, **75**, P 20176 p).

[14] E. R. H. Jones and F. Sondheimer, *J. Chem. Soc.*, 1949, 615.

(1.5 ml). When cool, the mixture was diluted with water (100 ml) and continuously extracted with chloroform for 20 h. The chloroform was dried and evaporated and the residue (250 mg, 90%) was crystallised from ether–petrol to give the oxime (3) (153 mg, 55%) as plates, m.p. 77—79° (lit.,[15] 78—79°), $\nu_{max.}$ 3 585 and 3 300 cm^{-1} (OH), τ 6.00 (C*H*OH) (Found: C, 56.0; H, 8.5; N, 10.8. Calc. for $C_6H_{11}NO_2$: C, 55.8; H, 8.6; N, 10.8%).

4-*Nitrocyclohexyl Benzoate* (4).—A solution of trifluoroperacetic acid was prepared by addition of 86% hydrogen peroxide (0.60 ml, *ca.* 20 mmol) to a stirred solution of trifluoroacetic anhydride (3.4 ml, 24 mmol) in acetonitrile (5 ml). This solution was added over 40 min to a mixture of 4-benzoyloxycyclohexanone oxime (2) (2.33 g, 10 mmol), urea (200 mg), and disodium hydrogen phosphate (7.8 g) stirred at 80 °C. After a further 1 h at 80 °C the mixture was cooled and partitioned between water and ether. The organic phase was washed successively with aqueous 5% sodium hydrogen carbonate, aqueous 2% sodium disulphite, and water, dried, and evaporated to a golden oil (2.28 g). Chromatography over silica gel (dichloromethane as eluant) afforded the *nitro-derivative* (4) as a white waxy solid (1.425 g, 57%), $\nu_{max.}$ 1 710 (ester) and 1 548 and 1 270 cm^{-1} (NO_2), τ 5.50 (1 H, m, $CHNO_2$) and 4.80 (1 H, m, C*H*OCOPh) (Found: C, 61.65; H, 6.0; N, 5.5. $C_{13}H_{15}NO_4$,0.25H_2O requires C, 61.5; H, 6.15; N, 5.5%).

(±)-6β-*Methyl*-3ξ-*nitro*-trans-*bicyclo*[4.3.0]*nonan*-7β-*ol* (30).—By the above method, the oxime (29) (5.92 g, 32.3 mmol) gave the crude nitro-compound (30) as a golden oil (3.98 g). Chromatography over silica gel [eluting with dichloromethane–ethanol (24 : 1)] afforded a golden *gum* (2.69 g, 42%), $\nu_{max.}$ 3 620 (OH) and 1 550 cm^{-1} (NO_2), τ 9.10 (3 H, s, CH_3), 6.30 (1 H, m, C*H*OH), and 5.60 (1 H, m, $CHNO_2$) (Found: C, 60.1; H, 8.55; N, 6.75. $C_{10}H_{17}NO_3$ requires C, 60.3; H, 8.6; N, 7.05%).

Methyl (4-*Nitrocyclohexyl*)*acetate* (12).—By the above method the oxime (24) (10.8 g, 58 mmol) yielded, after chromatography in dichloromethane over silica gel, the *nitro-ester* (12) as an oil (6.78 g, 54%), $\nu_{max.}$ 1 718 (ester) and 1 550 cm^{-1} (NO_2), τ 6.29 (3 H, s, CO_2CH_3) and 5.52 (1 H, m, $CHNO_2$) (Found: C, 53.9; H, 7.6; N, 7.1. $C_9H_{15}NO_4$ requires C, 53.7; H, 7.5; N, 7.0%).

1-(2-*Acetoxypropyl*)-4-*nitrocyclohexane* (13).—By the above method the oxime (27) (900 mg, 4.22 mmol) afforded the crude nitro-compound (13) (630 mg). P.l.c. ($CHCl_3$) yielded the *nitro-ester* (13) as an oil (280 mg, 29%), $\nu_{max.}$ 1 720 (ester) and 1 546 cm^{-1} (NO_2), τ 8.79 (3 H, d, *J* 6 Hz, CH_3), 7.95 (3 H, s, $OCOCH_3$), 5.60 (1 H, m, $CHNO_2$), and 5.00 (1 H, m, C*H*OAc) (Found: C, 57.6; H, 8.3; N, 5.9. $C_{11}H_{19}NO_4$ requires C, 57.6; H, 8.35; N, 6.1%).

1-(2-*Hydroxypropyl*)-4-*nitrocyclohexane* (14).—A solution of the acetate (13) (16.0 g, 70 mmol) in methanol (50 ml) containing perchloric acid (12 drops of 60%) was slowly distilled. The reaction volume was maintained by addition of methanol as necessary. After 7 h, the mixture was evaporated and the residue was partitioned between brine and dichloromethane. The organic phase was dried and evaporated to give the *nitro-alcohol* (14) as a yellow oil (12.8 g, 98%), $\nu_{max.}$ 3 630 (OH) and 1 545 cm^{-1} (NO_2), τ 8.81 (3 H, d, *J* 6 Hz, CH_3), 6.10 (1 H, m, C*H*OH), and 5.55 (1 H, m, $CHNO_2$) (Found: C, 57.6; H, 9.2; N, 7.3. $C_9H_{17}NO_3$ requires C, 57.7; H, 9.1; N, 7.5%).

(4-*Nitrocyclohexyl*)*acetone* (15).—Jones reagent (15 ml) was added dropwise over 2 h to a solution of the nitro-alcohol (14) (11.6 g, 62 mmol) in acetone (300 ml) at 0 °C. The mixture was stirred for a further 1 h, diluted with water, and extracted with ether. The extract was washed with water and evaporated with the aid of benzene to give the *nitro-ketone* (15) as a yellow oil (11.2 g, 98%), $\nu_{max.}$ 1 711 (C=O) and 1 550 and 1 382 cm^{-1} (NO_2), τ 7.88 (3 H, s, $COCH_3$) and 5.6 (1 H, m, $CHNO_2$) (Found: C, 58.4; H, 8.1; N, 7.2. $C_9H_{15}NO_3$ requires C, 58.35; H, 8.15; N, 7.55%).

4,4-*Dinitrocyclohexanol* (6).—A solution of 4-nitrocyclohexyl benzoate (4) (1.0 g, 4.01 mmol) in ethanol (40 ml) and water (60 ml) was heated under reflux with 2N-sodium hydroxide (4.1 ml) for 30 min. The solution was allowed to cool to room temperature and sodium nitrite (414 mg, 6 mmol) in water (10 ml) was added. The solution was then added to a rapidly stirred mixture of silver nitrate (1.4 g, 8.23 mmol), water (20 ml), ether (60 ml), and 2N-sodium hydroxide (2 drops) at 4 °C. A brown precipitate was formed immediately and the temperature rose to 10 °C. The precipitate gradually became darker and after 5 min the cooling bath was removed and the mixture was stirred for 30 min at room temperature, then filtered through kieselguhr. The residue was washed with ether and the filtrate was extracted with ether. The combined ethereal solutions were washed with water, dried, and evaporated. Crystallisation of the residue (521 mg, 68%) from ether–petrol gave 4,4-*dinitrocyclohexanol* (6) as off-white prisms (320 mg, 42%), m.p. 109—110°, $\nu_{max.}$ 3 610 (OH) and 1 570 cm^{-1} (NO_2), τ 8.41 (1 H, s, OH), 5.91 (1 H, m, C*H*OH), 6.6—7.7 (4 H, m, 3- and 5-H), and 7.9—8.5 (4 H, m, 2- and 6-H) (Found: C, 37.6; H, 5.3; N, 15.1. $C_6H_{10}N_2O_5$ requires C, 37.9; H, 5.3; N, 4.75%).

(±)-6β-*Methyl*-3,3-*dinitro*-trans-*bicyclo*[4.3.0]*nonan*-7β-*ol* (31).—The nitro-alcohol (30) (870 mg, 4.37 mmol) in ethanol (10 ml) was treated with aqueous 0.86M-potassium hydroxide (5.1 ml) and the nitro-salt was treated with sodium nitrite and silver nitrate as above. The crude product (915 mg, 86%) was recrystallised from ether–petrol to give the *dinitro-compound* (31) as needles (500 mg, 47%), m.p. 112—113°, $\nu_{max.}$ 3 625 (OH) and 1 575 cm^{-1} (NO_2), τ 9.10 (3 H, s, CH_3) and 6.28 (1 H, m, C*H*OH) (Found: C, 49.2; H, 6.55; N, 11.5. $C_{10}H_{16}N_2O_5$ requires C, 49.2; H, 6.5; N, 11.45%).

4,4-*Dinitrocyclohexanone* (7).—A solution of 4,4-dinitrocyclohexanol (6) (2.0 g, 10.5 mmol) in acetone (30 ml) was treated dropwise over 2 h with Jones reagent (2.6 ml). The mixture was stirred for a further 1 h, diluted with water, and extracted with ether. The extract was washed with water, dried, and evaporated to a waxy solid (1.87 g, 94%). A portion (750 mg) was subjected to p.l.c. (CH_2Cl_2) to give 4,4-*dinitrocyclohexanone* (7) as a white crystalline solid (510 mg, 64%), m.p. 109—110°, $\nu_{max.}$ 1 730 (C=O) and 1 575 cm^{-1} (NO_2) (Found: C, 38.3; H, 4.3; N, 14.8. $C_6H_8N_2O_5$ requires C, 38.3; H, 4.25; N, 14.9%).

4-*Nitro*-4-(1-*nitrocyclohexyl*)*cyclohexyl Benzoate* (8).—4-Nitrocyclohexyl benzoate (4) (974 mg, 3.9 mmol) in dry methanol (20 ml) was treated with 1.7N-lithium methoxide in methanol (2.32 ml, 3.95 mmol) and the solution was immediately evaporated to dryness under reduced pressure. The residue was dissolved in dry dimethyl sulphoxide (20 ml) and the red solution was degassed and stirred under nitrogen. 1,1-Dinitrocyclohexane (5) (680 mg, 3.9 mmol) in dry dimethyl sulphoxide (10 ml) was added and the mixture was irradiated for 2 h with eight 20 W ' Daylight ' fluorescent tubes. 0.1N-Hydrochloric acid (40 ml) and water (160 ml) were added and the mixture was stirred for

[15] W. F. Trager and A. C. Huitric, *J. Pharm. Sci.*, 1967, **56**, 1111.

5 min, then stored at 0 °C for 1 h. The resulting pale green solid (1.265 g, 86%) was collected, washed with water, and recrystallised from acetone to give the *vic-dinitro-compound* (8) as prisms (219 mg, 15%), m.p. 226—232° (decomp.), $\nu_{max.}$ 1 705 (ester) and 1 545 cm^{-1} (NO_2), τ ($CF_3{\cdot}CO_2H$) 4.90 (1 H, m, C*H*OCOPh) (Found: C, 60.6; H, 6.4; N, 7.5. $C_{19}H_{24}N_2O_6$ requires C, 60.65; H, 6.45; N, 7.45%).

4-Hydroxy- (17) *and 4-Benzoyloxy-1,1′-bi(cyclohexylidene)* (9).—A solution of the *vic*-dinitro-compound (8) (2.7 g, 7.25 mmol) in dimethylformamide (50 ml) was treated with finely ground sodium sulphide nonahydrate (4.3 g, 17.95 mmol) and the stirred solution was irradiated under nitrogen for 5 h with eight 20 W fluorescent tubes, then partitioned between water and dichloromethane. The organic phase was washed with water, dried, and evaporated. P.l.c. of the residue yielded as the less polar fraction a white solid (888 mg, 39%) which crystallised from ether–petrol to give the *benzoate* (9) as rods, m.p. 75—76°, $\nu_{max.}$ 1 708 cm^{-1} (ester), τ 4.80 (1 H, m, C*H*OCOPh) (Found: C, 79.1; H, 8.4. $C_{19}H_{24}O_2$,0.25H_2O requires C, 79.1; H, 8.5%). The more polar fraction (500 mg, 38%) crystallised from ether–petrol to give the *alcohol* (17) as needles, m.p. 115°, $\nu_{max.}$ 3 610 cm^{-1} (OH), τ 6.15 (1 H, m, C*H*OH) (Found: C, 79.6; H, 11.5. $C_{12}H_{20}O$ requires C, 79.9; H, 11.2%).

4-Nitro-4-(1-nitrocyclohexyl)cyclohexanol (16; R = H).—Nitrocyclohexane (1.36 g, 10.54 mmol) was treated as above with methanolic lithium methoxide (10.75 mmol) and the resulting nitro-salt was irradiated for 6.5 h in dimethyl sulphoxide with 4,4-dinitrocyclohexanol (6) (2.0 g, 10.54 mmol). The product (1.9 g, 66%) was crystallised from ether–dichloromethane to give the vic-*dinitro-compound* (16; R = H) as off-white prisms, m.p. 202—204°, $\nu_{max.}$ 3 605 and 3 400 (OH) and 1 550 cm^{-1} (NO_2), τ 7.40 (Me_2SO) and 6.50 (1 H, m, C*H*OH) (Found: C, 51.0; H, 7.3; N, 9.6; S, 2.4. $C_{12}H_{20}N_2O_5$,0.25Me_2SO requires C, 50.9; H, 7.5; N, 9.7; S, 2.7%). Irradiation of the product with sodium sulphide in dimethylformamide, as above, afforded 4-hydroxy-1,1′-bi(cyclohexylidene) (17) [4] (36%).

Condensation of Nitrocyclohexane and 4,4-Dinitrocyclohexanol in Dimethylformamide.—Nitrocyclohexane (680 mg, 5.27 mmol) in dry methanol (12 ml) was treated with 1.6N-lithium methoxide in methanol (3.36 ml, 5.37 mmol) and the solution was evaporated to dryness. 4,4-Dinitrocyclohexanol (6) (1.0 g, 5.27 mmol) in dimethylformamide (60 ml) was added and the stirred mixture was degassed and irradiated under nitrogen for 6 h as above. Finely ground sodium sulphide nonahydrate (3.8 g, 15.8 mmol) was added and irradiation was continued for a further 4 h. The mixture was partitioned between water and dichloromethane and the organic phase was washed with water, dried, and evaporated. Chromatography of the residue over silica gel yielded 4-hydroxy-1,1′-bi(cyclohexylidene) (17) [4] (670 mg, 70%).

1,1′-Bi(cyclohexyliden)-4-one (10).—Nitrocyclohexane (681 mg, 5.32 mmol) was converted into its lithium salt and irradiated for 7.5 h in dimethylformamide with 4,4-dinitrocyclohexanone (7) (1.0 g, 5.32 mmol). Sodium sulphide nonahydrate (3.8 g, 15.8 mmol) was added and irradiation was continued for 2 h. Work-up as above yielded a brown gum (690 mg) which was subjected to repeated p.l.c. (CH_2Cl_2) to give the ketone (10) (51 mg, 5%) as a gum, $\nu_{max.}$ 1 700 cm^{-1} (C=O), τ 7.0—8.0 (12 H, m, 2-, 3-, 5-, 6-, 2′-, and 6′-H) and 8.1—8.7 (6 H, m, 3′-, 4′-, and 5′-H), for which a correct elemental analysis was not obtained.

4,4′-Dihydroxy-1,1′-bi(cyclohexylidene) (18).—A stirred solution of 4,4-dinitrocyclohexanol (6) (380 mg, 2 mmol) and 4-nitrocyclohexyl benzoate (4) (498 mg, 2 mmol) in dry degassed dimethyl sulphoxide (20 ml) was treated under nitrogen with n-butyl-lithium in hexane (1.6 ml of 3M; 4.8 mmol) and irradiated for 2 h as above. The mixture was then poured into water, acidified, and extracted with dichloromethane. The extract was washed with water and evaporated to a brown oil which was irradiated under nitrogen for 2 h in dimethylformamide (20 ml) containing sodium sulphide nonahydrate (2.4 g, 10 mmol). Work-up as above gave a brown solid (240 mg) which was subjected to p.l.c. (CH_2Cl_2–MeOH, 19 : 1) to give the diol [4] (18) (113 mg, 29%). Comparison of this material by t.l.c. with the pure *cis-* and *trans*-isomers of (18) showed that it was a 1 : 1 mixture of the two isomers.

4-Acetonyl-4′-hydroxy-1,1′-bi(cyclohexylidene) (21).—1-Acetonyl-4-nitrocyclohexane (15) (555 mg, 3 mmol) was converted into its lithium salt as described above and irradiated under nitrogen in dimethyl sulphoxide containing 4,4-dinitrocyclohexanol (6) (570 mg, 3 mmol). After 3.5 h more lithium methoxide (3.1 mmol) was added and irradiation was continued for a further 1.5 h. The usual work-up gave the crude *vic*-dinitro-compound, which was irradiated along with sodium sulphide in dimethylformamide for 2 h. The crude product (650 mg) was purified by p.l.c. ($CHCl_3$–EtOAc, 5 : 1) to give a solid (410 mg, 58%), which was crystallised from ether–petrol to give the *olefin* (21) as needles, m.p. 116—125°, $\nu_{max.}$ 3 615 (OH) and 1 710 cm^{-1} (C=O), τ 7.74 (3 H, s, CH_3) and 6.20 (1 H, m, C*H*OH) (Found: C, 75.0; H, 10.0. $C_{15}H_{24}O_2$,0.25H_2O requires C, 74.8; H, 10.25%).

4-Hydroxy-4′-methoxycarbonylmethyl-1,1′-bi(cyclohexylidene) (20) *and 4-Carboxymethyl-4′-hydroxy-1,1′-bi(cyclohexylidene)* (19).—The reaction of 4,4-dinitrocyclohexanol (6) (570 mg, 3 mmol) with methyl (4-nitrocyclohexyl)-acetate (12) (604 mg, 3 mmol) proceeded exactly as in the previous experiment. The mixture was partitioned between water and dichloromethane, and the organic phase was washed with water, dried, and evaporated to a gum (130 mg). The combined aqueous phases were acidified and extracted with dichloromethane. The extract was washed with water, dried, and evaporated to a solid (650 mg). The combined products were subjected to p.l.c. ($CHCl_3$–EtOAc, 2 : 1) to give as the less polar fraction the *ester* (20) (50 mg, 7%), m.p. 106—110°, $\nu_{max.}$ 3 620 (OH) and 1 728 cm^{-1} (ester), τ 6.35 (3 H, s, CH_3) and 6.20 (1 H, m, C*H*OH) (Found: C, 68.9; H, 9.4. $C_{15}H_{24}O_3$,0.5H_2O requires C, 68.95; H, 9.6%). The more polar fraction (310 mg, 43%) was crystallised from acetone–petrol to give the *acid* (19) (50 mg, 7%), m.p. 162—166°, $\nu_{max.}$ 3 600 and 3 600—3 200 (OH), and 1 730 and 1 710 cm^{-1} (CO_2H), τ 3.50br (1 H, m, CO_2H) and 6.25 (1 H, m, C*H*OH) (Found: C, 69.4; H, 9.1. $C_{14}H_{22}O_3$,0.25H_2O requires C, 69.25; H, 9.3%).

(±)-*6,7-Dinor-5,8-secoestr-9-ene-3ξ,17β-diol* (33).—The reaction between the dinitro-alcohol (31) (350 mg, 1.43 mmol) and 4-nitrocyclohexyl benzoate (4) (357 mg, 1.43 mmol) was carried out as in the previous two experiments. P.l.c. (acetone–petrol, 1 : 4) furnished the olefin (33) (120 mg) contaminated with the hydroxy-ketone (28). This material was stirred rapidly with ether and aqueous 10% sodium disulphite for 45 min. Evaporation of the ethereal solution yielded the olefin (33) (45 mg, 12.5%), identical (i.r., n.m.r., and g.l.c.) with the authentic 3β-isomer.[4]

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