# Acid-catalysed Reactions of 1α,2α-Epoxy-1β-methyl- and 1α-Hydroxy-1β-methyl-5α-steroids

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The reaction of 1α,2α-epoxy-1β-methyl-5α-androstane-3β,17β-diol diacetate (4) with boron trifluoride–ether leads to both the A-nor derivative (5) and the 2α-hydroxy-1-methylene compound (6). The epoxide (4) on treatment with acetic anhydride–acetic acid and toluene-*p*-sulphonic acid gives, depending upon temperature, the 1α,2β-diacetoxy-compound (11) or the 2β-acetoxy-1-methylene compound (12), while with formic acid gives the 2-formate (13) of the 1α,2β-diol. The reaction of 1α,2α-epoxy-1β-methyl-5α-androstane-3α,17β-diol diacetate (14) with boron trifluoride affords the A-noraldehyde (15) and the 1-methylene derivative (16). 1β-Methyl-5α-androstane-1α,3β,17β-triol 3,17-diacetate (19) with toluene-*p*-sulphonic acid is simply acetylated to give (20) and dehydrated to give (21).

THE acid-catalysed reactions of steroidal 4,5- and 5,6-epoxides are known to be sensitive to changes in substituents at C(3).[1] The behaviour of 1α,2α-epoxy-1β-methyl-3-oxo-5α-androstanes [2] and, more recently, of 1,2-epoxy-3-hydroxy(or acetoxy)-5α-cholestanes,[3] with nucleophiles has been reported. In the present work we describe the reaction of 1α,2α-epoxy-1β-methyl-5α-androstane-3β,17β-diol diacetate (4) with boron trifluoride–ether, with toluene-*p*-sulphonic acid in acetic anhydride–acetic acid, and with formic acid, and the reaction of the stereoisomeric 3α-acetoxy-epoxide (14) with boron trifluoride in order to determine the influence of the presence of a 3-acetoxy-group.

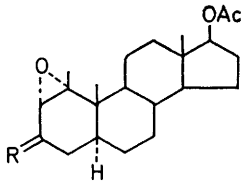
*Preparation and Rearrangements of the* 1α,2α-*Epoxides* (4) *and* (14).—Reduction with sodium borohydride in the presence of deactivated alumina [4] of the epoxy-ketone (1) gave a 1 : 3 mixture of 3α- (2) and 3β-hydroxy-epoxy-17-acetates (3) purified by column chromatography.† Reaction of a 5% benzene solution of the 3β-acetoxy-1α,2α-epoxide (4) with boron trifluoride–ether for 5 min at room temperature gave a mixture from which the 1α-formyl-A-nor-2β-acetoxy derivative (5) (35%) and the 2-hydroxymethylene-diacetate (6) (42%) were isolated by p.l.c. The A-noraldehyde (5) was identified by the singlet (CHO) at δ 9.97 in its $^1$H n.m.r. spectrum. The configuration at C(1) of compound (5) was determined by its conversion into the 1β-methyl-A-nor-5α-androstane-2,17-dione (9) known.[2] Thus, on oxidation with Jones reagent, the A-noraldehyde (5) gave a diacetoxy-acid, which, after hydrolysis, afforded 1β-methyl-A-nor-5α-androstane-2β,17β-diol-1α-carboxylic acid (7), which, on oxidation with chromium trioxide in acetic acid and decarboxylation, afforded the known diketone (9).[2] The C(2) configuration of the methylene-hydroxy-compound (6) was assigned on the basis of $J_{2,3}$ values of its acetyl derivative (10), compared with those of the methylene compound (12), described below. The $^1$H n.m.r. spectrum of the acetate (10) showed signals for methylene protons at δ 4.75 and 4.96 and those of methyls of the acetoxy-groups at δ 2.02 (6 H) and 2.08 (3 H).

Reaction of an acetic anhydride–acetic acid solution of the 3β-acetoxy-1α,2α-epoxide (4) with toluene-*p*-sulphonic acid gave at room temperature the tetra-acetate (11) (58%) which was readily identified by its characteristic $^1$H n.m.r. spectrum in which the four methyls of the acetoxy-groups are present at δ 1.96, 2.05, 2.07, and 2.12. The reaction of the epoxide (4) with the same reagent at 100° for 1 h led instead to the methylene derivative (12) (81%) which in its $^1$H n.m.r. spectrum showed the methylene protons at δ 4.95 and 5.22, and those of the three methyls of the acetoxy-groups at δ 2.00, 2.03, and 2.06. Upon examining the $J_{2,3}$ values, in order to assign the C(2) configuration of the methylene compounds (10) and (12), for (12) we measured $J_{2\alpha,3\alpha}$ 4 Hz and for (10) $J_{2\beta,3\alpha}$ 10 Hz. As these experimental values are in accord with theoretical ones calculated from the Karplus equation,[5] we could assign the 2β configuration to (12) and the 2α configuration to (10). We have also noted the conversion of the tetra-acetate (11) with toluene-*p*-sulphonic acid at 100° for 1 h in acetic anhydride–acetic acid solution into the methylene triacetate (12) (65%).

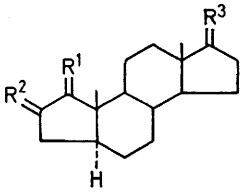
The reaction of the epoxide (4) with formic acid at room temperature gave 1α-hydroxy-2β-formyloxy-compound (13) (94%), characterized by the presence of the 1-methyl signal at δ 1.39 and of the formate proton at δ 8.04 in its $^1$H n.m.r. spectrum.

The different mode of scission of the 3β-acetoxy-1α,2α-epoxide (4), observed here, may be interpreted in terms of the nature of the reagents employed. The electrophilic boron trifluoride, together with the $-I$ effect of the 3-acetoxy-group, leads to epoxide opening at the more alkylated carbon centre, and either C(2)–C(3) bond migration or $H^+$ loss from the 1-methyl group, affording the A-noraldehyde (5) and the methylene derivative (6) respectively, takes place. The ring contraction probably follows a concerted pathway with epoxide opening leading to the A-nor compound (5) with

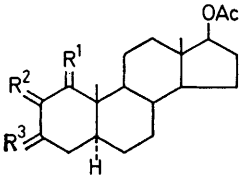
† The percentages of the two hydroxy-derivatives (2) and (3) are in agreement with proportions of the two epimeric bromohydrins, obtained by reduction of 2α-bromo-5α-cholestan-3-one reported by L. F. Fieser and Wei Yuan Huang, *J. Amer. Chem. Soc.*, 1953, **75**, 4837. Chemical shifts of protons at C-3 of compounds (2) and (3) are also in accord with the configuration at C-3 assigned on the basis of literature data (L. M. Jackman, 'Applications of N.M.R. Spectroscopy in Organic Chemistry,' Pergamon, London, 1959, pp. 115 *et seq.*).



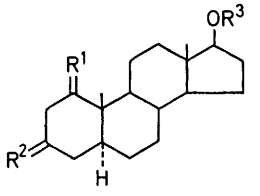
(1) R = O
(2) R = α-OH, H
(3) R = β-OH, H
(4) R = β-OAc, H
(14) R = α-OAc, H



(5) $R^1$ = α-CHO, Me, $R^2$ = β-OAc, H, $R^3$ = β-OAc, H
(7) $R^1$ = α-COOH, Me, $R^2$ = β-OH, H, $R^3$ = β-OH, H
(8) $R^1$ = α-COOMe, Me, $R^2$ = β-OH, H, $R^3$ = β-OH, H
(9) $R^1$ = β-Me, H, $R^2$ = $R^3$ = O
(15) $R^1$ = α-CHO, Me, $R^2$ = α-OAc, H, $R^3$ = β-OAc, H



(6) $R^1$ = $CH_2$, $R^2$ = α-OH, H, $R^3$ = β-OAc, H
(10) $R^1$ = $CH_2$, $R^2$ = α-OAc, H, $R^3$ = β-OAc, H
(11) $R^1$ = α-OAc, Me, $R^2$ = β-OAc, H, $R^3$ = β-OAc, H
(12) $R^1$ = $CH_2$, $R^2$ = β-OAc, H, $R^3$ = β-OAc, H
(13) $R^1$ = α-OH, Me, $R^2$ = β-OCHO, H, $R^3$ = β-OAc, H
(16) $R^1$ = $CH_2$, $R^2$ = α-OAc, H, $R^3$ = α-OAc, H



(17) $R^1$ = α-OH, Me, $R^2$ = α-OH, H, $R^3$ = H
(18) $R^1$ = α-OH, Me, $R^2$ = β-OH, H, $R^3$ = H
(19) $R^1$ = α-OH, Me, $R^2$ = β-OAc, H, $R^3$ = Ac
(20) $R^1$ = α-OAc, Me, $R^2$ = β-OAc, H, $R^3$ = Ac
(21) $R^1$ = $CH_2$, $R^2$ = β-OAc, H, $R^3$ = Ac

the same 1-methyl configuration. The behaviour of the epoxide (4) with toluene-*p*-sulphonic acid and formic acid, notwithstanding the presence of the neighbouring 3-acetoxy-group, is subject only to conformational control, leading to nucleophilic cleavage diaxial products.

In order to determine the influence of the configuration at C(3) on boron trifluoride rearrangement products, we examined the reaction of a 5% benzene solution of the 3α-acetoxy-1α,2α-epoxide (14) with this reagent for 5 min at room temperature. We obtained a mixture from which two major fractions were separated by p.l.c. The former gave the A-noraldehyde (15) (50%), and the latter, after acetylation and p.l.c., afforded the 1-methylene-2α,3α,17β-triacetate (16) (22%). The A-noraldehyde (15) showed the singlet (CHO) at δ 9.75 in its $^1$H n.m.r. spectrum, while the methylene triacetate (16) exhibited the signals of the methylene protons at δ 4.84 and 4.95 and those of methyls of the acetoxy-groups at δ 2.00 (6 H) and 2.02 (3 H). As we may note for the boron trifluoride-catalysed reaction of the two stereoisomeric 3-acetoxy-epoxides (4) and (14) the configuration at C(3) does not appear to be particularly important. In fact the reaction leads always to the same products [A-noraldehydes (5) and (15) and 1-methylene derivatives (6) and (16)], and only the yields are affected.

*Preparation and Rearrangement of the* 1α-*Hydroxy-compound* (19).—The reduction with lithium aluminium hydride of the epoxide (1) gave a mixture of two epimeric triols (17) and (18), which presented a different solubility and therefore were separated without difficulty. By acetylation, the triol (18) gave the 1α-hydroxy-3β,17β-diacetoxy-compound (19), which, treated with toluene-*p*-sulphonic acid, gave the triacetate (20) and the 1-methylene-3β,17β-diacetoxy-derivative (21). The latter was useful in further confirming the configuration of the 1-methylene-2α-hydroxy-3β,17β-diacetate (6), described above. Thus by tosylation at C(2) and reduction with lithium aluminium hydride the methylene derivative (6) afforded the same 1-methylene-3β,17β-diacetate (21). No very important data are available on the acid-catalysed reaction of the 1α-hydroxy-3β-acetoxy-compound (19), because, as we noted for rearrangement of epoxide (4) with toluene-*p*-sulphonic acid, the 3-acetoxy-group does not appear to have a great influence on this reaction. The mechanism probably proceeds through a carbonium ion and gives only the exocyclic methylene derivative (21), which is more stable than the 1-methyl-Δ$^1$-compound (*cf.* ref. 1*a*, p. 104).

## EXPERIMENTAL

M.p.s were measured with a Büchi oil-bath apparatus. Optical rotations were taken at room temperature for solution in chloroform, unless specified otherwise, in a 1 dm cell with a Schmidt–Haensch polarimeter. I.r. spectra (KBr discs) were recorded on a Perkin-Elmer 521 grating spectrophotometer. $^1$H N.m.r. spectra were measured for solutions in deuteriochloroform (unless specified otherwise) (tetramethylsilane as internal standard) with a Varian A-60 or JEOL C-60 HL spectrometer. P.l.c. was carried out with Merck $HF_{254}$ silica gel (layers 0.5 mm thick). Alumina used for column chromatography was Woelm neutral.

*Preparation of Epoxy-alcohols* (2) *and* (3).—To a mixture of sodium borohydride (0.75 g) in water (1.9 ml) and deactivated alumina (Brockman grade III) (15 g) a solution of the epoxy-ketone [2] (1) (1.5 g) in dry benzene (50 ml) was added according to the literature procedure.[4] The solution

was filtered, evaporated, and the crude product (1.43 g) was chromatographed on deactivated alumina (Brockman grade III) (145 g). Elution with benzene–chloroform (1 : 9) gave 1α,2α-*epoxy*-1β-*methyl*-5α-*androstane*-3α,17β-*diol* 17-*monoacetate* (2) (330 mg), m.p. 157—158° (from di-isopropyl ether), $[\alpha]_D$ −25° (*c* 2.37), $\nu_{max.}$ 3 570 and 1 723 $cm^{-1}$, δ 0.79 (3 H, s, 13-Me), 0.96 (3 H, s, 10-Me), 1.44 (3 H, s, 1β-Me), 2.03 (3 H, s, 17β-OAc), and 4.08 (1 H, m, 3β-H) (Found: C, 73.05; H, 9.5. $C_{22}H_{34}O_4$ requires C, 72.9; H, 9.45%), and 1α,2α-*epoxy*-1β-*methyl*-5α-*androstane*-3β,17β-*diol* 17-*monoacetate* (3) (1 g), m.p. 159—161° (from di-isopropyl ether), $[\alpha]_D$ +4.8° (*c* 1.36), $\nu_{max.}$ 3 490 and 1 710 $cm^{-1}$, δ 0.78 (3 H, s, 13-Me), 1.01 (3 H, s, 10-Me), 1.42 (3 H, s, 1β-Me), 2.03 (3 H, s, 17β-OAc), and 3.87 (1 H, m, 3α-H) (Found: C, 73.2; H, 9.55%).

1α,2α-*Epoxy*-1β-*methyl*-5α-*androstane*-3β,17β-*diol Diacetate* (4).—Acetylation of the 3β-hydroxy-1α,2α-epoxide (3) (3.08 g) with acetic anhydride–pyridine overnight at room temperature gave the diacetoxy-epoxide (4) (3.47 g), m.p. 119—120° (from hexane), $[\alpha]_D$ −4.5° (*c* 3.0), $\nu_{max.}$ 1 725 $cm^{-1}$, δ 0.80 (3 H, s, 13-Me), 1.03 (3 H, s, 10-Me), 1.43 (3 H, s, 1β-Me), 2.03 (3 H, s, 3β- or 17β-OAc), and 2.07 (3 H, s, 17β- or 3β-OAc) (Found: C, 71.35; H, 8.95. $C_{24}H_{36}O_5$ requires C, 71.25; H, 8.95%).

*Reaction of* 3β-*Acetoxy*-1α,2α-*epoxide* (4) *with Boron Trifluoride*.—A solution of the acetoxy-epoxide (4) (1 g) in dry benzene (20 ml) was treated with boron trifluoride–ether complex (0.9 ml) and set aside for 5 min. The solvent was removed and ether was added. The organic layer, washed with water, sodium hydrogencarbonate solution, and water, dried ($Na_2SO_4$), and evaporated, gave a residue (1 g). P.l.c. of 330 mg [benzene–ether (9 : 1) as eluant] afforded 1β-*methyl*-1α-*formyl*-A-*nor*-5α-*androstane*-2β,17β-*diol diacetate* (5) (115 mg), m.p. 159—160° (from di-isopropyl ether), $[\alpha]_D$ −21° (*c* 0.73), $\nu_{max.}$ 2 745, 1 728, and 1 703 $cm^{-1}$, δ 0.78 (3 H, s, 13-Me), 1.11 (3 H, s, 10-Me), 1.24 (3 H, s, 1β-Me), 2.01 (3 H, s, 2β- or 17β-OAc), 2.02 (3 H, s, 17β- or 2β-OAc), and 9.97 (1 H, s, 1α-CHO) (Found: C, 71.3; H, 8.95. $C_{24}H_{36}O_5$ requires C, 71.25; H, 8.95%), and a second fraction, which gave 1-*methylene*-5α-*androstane*-2α,3β,17β-*triol* 3,17-*diacetate* (6) (140 mg), m.p. 129—130° (after crystallization from di-isopropyl ether–hexane and further sublimation at 145° and 0.1 mmHg), $[\alpha]_D$ +44° (*c* 1.0), $\nu_{max.}$ 1 735, 1 708, and 1 635 $cm^{-1}$, δ 0.83 (3 H, s, 13-Me), 0.98 (3 H, s, 10-Me), 2.04 (3 H, s, 3β- or 17β-OAc), 2.10 (3 H, s, 17β- or 3β-OAc), 4.93, and 5.37br (2 H, $CH_2$=C) (Found: C, 71.05; H, 8.95. $C_{24}H_{36}O_5$ requires C, 71.25; H, 8.95%).

1β-*Methyl*-2β,17β-*dihydroxy*-A-*nor*-5α-*androstane*-1α-*carboxylic Acid* (7).—A solution of A-noraldehyde (5) (300 mg) in acetone (16 ml; distilled over $KMnO_4$) was treated dropwise with Jones reagent (1.12 ml) and kept at room temperature for 4 h. Isopropyl alcohol was added and the solution was diluted with water and extracted with ether. The organic layers were washed with 2N-sodium hydroxide solution and the alkaline fraction was kept at room temperature overnight, then acidified with 2N-hydrochloric acid, and extracted with ether. The combined extracts, washed with water and dried ($Na_2SO_4$), gave the *dihydroxy*-1α-*carboxy-compound* (7) (185 mg), m.p. 258—261° (from methanol), $[\alpha]_D$ −11° (*c* 1.0 DMSO), $\nu_{max.}$ 1 705 $cm^{-1}$, δ ($C_5D_5N$) 0.99 (3 H, s, 13-Me), 1.47 (3 H, s, 10- or 1β-Me), and 1.55 (3 H, s, 1β- or 10-Me) (Found: C, 71.2; H, 9.6. $C_{20}H_{32}O_4$ requires C, 71.4; H, 9.6%).

*Methyl* 1β-*Methyl*-2β,17β-*dihydroxy*-A-*nor*-5α-*androstane*-1α-*carboxylate* (8).—Carboxylic acid (7) (73 mg), esterified with ethereal diazomethane, gave the *methyl ester* (8) (73 mg), m.p. 251—253° (from methanol), $\nu_{max.}$ 3 480, 3 390, and 1 715 $cm^{-1}$ (Found: C, 71.75; H, 9.75. $C_{21}H_{34}O_4$ requires C, 71.95; H, 9.8%).

1β-*Methyl*-A-*nor*-5α-*androstane*-2,17-*dione* (9).—To a solution of the carboxylic acid (7) (60 mg) in acetic acid (13 ml; distilled over $CrO_3$) chromium trioxide (48 mg) in acetic acid–water (5 : 1) (10 ml) was added. The mixture was kept at room temperature for 8 h and the usual work-up gave a crude product (62 mg), which sublimed *in vacuo* (30 mmHg) at 230—240° to afford the A-*nordione* [2] (9) (29 mg), m.p. 147—148° (from hexane), $[\alpha]_D$ +232° (*c* 1.0), $\nu_{max.}$ 1 743 and 1 731 $cm^{-1}$, δ 0.75 (3 H, s, 10-Me), 0.89 (3 H, s, 13-Me), and 1.10 (3 H, d, *J* 7 Hz, 1β-Me) (Found: C, 78.9; H, 9.75. $C_{19}H_{28}O_2$ requires C, 79.1; H, 9.8%).

1-*Methylene*-5α-*androstane*-2α,3β,17β-*triol Triacetate* (10).—Acetylation of the dihydroxy-compound (6) (50 mg) with acetic anhydride in pyridine at room temperature overnight gave the triacetate (10) (52 mg), m.p. 190—191° (from hexane), $[\alpha]_D$ +25° (*c* 1.0), $\nu_{max.}$ 1 735 and 1 630 $cm^{-1}$, δ 0.83 (3 H, s, 13-Me), 1.07 (3 H, s, 10-Me), 2.02 (6 H, s, 2α- and 3β-OAc, 2α- and 17β-OAc, or 3β- and 17β-OAc), 2.08 (3 H, s, 2α-, 3β-, or 17β-OAc), 4.75 and 4.96br (2 H, $CH_2$=C), and 5.48 (1 H, d, *J* 10 Hz, 2β-H) (Found: C, 70.05; H, 8.6. $C_{26}H_{38}O_6$ requires C, 69.9; H, 8.6%).

*Reaction of* 3β-*Acetoxy*-1α,2α-*epoxide* (4) *with Toluene*-p-*sulphonic Acid*.—(a) A solution of the epoxide (4) (205 mg) in acetic acid (3.3 ml) and acetic anhydride (3.3 ml) was treated with toluene-*p*-sulphonic acid (40 mg) and set aside at room temperature for 24 h. The solution was poured into brine and the resultant mixture was extracted with ether. The combined extracts were washed with sodium hydrogencarbonate solution and water, dried ($Na_2SO_4$), and evaporated to give 1β-*methyl*-5α-*androstane*-1α,2β,3β,17β-*tetrol tetra-acetate* (11) (150 mg), m.p. 218—219° (from di-isopropyl ether), $[\alpha]_D$ −18° (*c* 1.0), $\nu_{max.}$ 1 750 and 1 725br $cm^{-1}$, δ 0.78 (3 H, s, 13-Me), 1.08 (3 H, s, 10-Me), 1.69 (3 H, s, 1β-Me), 1.96 (3 H, s, 1α-, 2β-, 3β-, or 17β-OAc), 2.05 (3 H, s, 1α-, 2β-, 3β-, or 17β-OAc), 2.07 (3 H, s, 1α-, 2β-, 3β-, or 17β-OAc), 2.12 (3 H, s, 1α-, 2β-, 3β-, or 17β-OAc), 5.00 (1 H, m, 3α-H), and 6.13 (1 H, d, *J* 4 Hz, 2α-H, collapsed to s on irradiation at δ 5.00) (Found: C, 66.3; H, 8.35. $C_{28}H_{42}O_8$ requires C, 66.4; H, 8.35%). The tetra-acetate (11) was hydrolysed in 5% methanolic potassium hydroxide solution at room temperature overnight. Dilution with water and extraction with ether in the usual way gave the corresponding tetrol, m.p. 206—207° (from ethyl acetate), $\nu_{max.}$ 3 400 $cm^{-1}$.

(b) The epoxide (4) (220 mg) was treated with AcOH (3.5 ml), $Ac_2O$ (3.5 ml), and toluene-*p*-sulphonic acid (42 mg) at 100° for 1 h. The usual work-up gave the 1-*methylene*-5α-*androstane*-2β,3β,17β-*triol triacetate* (12) (190 mg), m.p. 167—168° (from hexane), $[\alpha]_D$ +73° (*c* 1.0), $\nu_{max.}$ 1 735 and 1 628 $cm^{-1}$, 0.83 (3 H, s, 13-Me), 1.07 (3 H, s, 10-Me), 2.00 (3 H, s, 2β-, 3β-, or 17β-OAc), 2.03 (3 H, s, 2β-, 3β-, or 17β-OAc), 2.06 (3 H, s, 2β-, 3β-, or 17β-OAc), 4.95 and 5.22br (2 H, $CH_2$=C), and 5.57 (1 H, d, *J* 4 Hz, 2α-H) (Found: C, 69.85; H, 8.65. $C_{26}H_{38}O_6$ requires C, 69.95; H, 8.6%). The same 1-*methylene-triacetate* (12) (64 mg) was obtained when the tetra-acetate (11) (115 mg) was kept in AcOH–$Ac_2O$ and toluene-*p*-sulphonic acid at 100° for 1 h.

*Reaction of* 3β-*Acetoxy*-1α,2α-*epoxide* (4) *with Formic Acid*.—The epoxide (4) (200 mg) was treated with formic acid

(16 ml) at room temperature for 48 h. The solution was poured into brine and extracted with ether. The combined extracts were washed with sodium hydrogencarbonate solution and water, dried ($Na_2SO_4$), and evaporated to give 2-*formyloxy*-1β-*methyl*-1α,2β,3β,17β-*tetrol* 3,17-*diacetate* (13) (210 mg), m.p. 202—203° (from ethyl acetate), $[\alpha]_D$ +13° (*c* 1.0), $\nu_{max.}$ 3 440, 1 750, and 1 715 $cm^{-1}$, δ 0.78 (3 H, s, 13-Me), 1.03 (3 H, s, 10-Me), 1.38 (3 H, s, 1β-Me), 2.05 (3 H, s, 3β- or 17β-OAc), 2.14 (3 H, s, 17β- or 3β-OAc), 5.09 (1 H, apparent d, *J* 4 Hz, 2α-H), and 8.01 (1 H, d, *J* 1 Hz, 2β-OCHO) (Found: C, 65.95; H, 8.45. $C_{25}H_{38}O_7$ requires C, 66.65; H, 8.5%). Hydrolysis of the formate (13) with 5% methanolic potassium hydroxide solution at room temperature gave a tetrol, identical with the tetrahydroxy-derivative obtained from compound (11).

1α,2α-*Epoxy*-1β-*methyl*-5α-*androstane*-3α,17β-*diol Diacetate* (14).—Acetylation of the 3α-hydroxy-1α,2α-epoxide (2) (670 mg) with acetic anhydride–pyridine overnight at room temperature gave the diacetoxy-epoxide (14) (740 mg), m.p. 126—127° (from hexane), $[\alpha]_D$ −52.5° (*c* 1.0), $\nu_{max.}$ 1 730 $cm^{-1}$, δ 0.80 (3 H, s, 13-Me), 0.97 (3 H, s, 10-Me), 1.43 (3 H, s, 1β-Me), 2.03 (3 H, s, 3α- or 17β-OAc), and 2.10 (3 H, s, 17β- or 3α-OAc) (Found: C, 71.2; H, 8.95. $C_{24}H_{36}O_5$ requires C, 71.25; H, 8.95%).

*Reaction of* 3α-*Acetoxy*-1α,2α-*epoxide* (14) *with Boron Trifluoride.*—A solution of the acetoxy-epoxide (14) (1.7 g) in dry benzene (34 ml) was treated with boron trifluoride–ether complex (1.5 ml) and set aside for 5 min. The usual work-up gave a residue (1.8 g) which, purified by p.l.c. [benzene–ether (9 : 1) as eluant, two runs], afforded 1β-*methyl*-1α-*formyl*-A-*nor*-5α-*androstane*-2α,17β-*diol diacetate* (15) (845 mg), m.p. 119—122° (from hexane), $[\alpha]_D$ +18.3° (*c* 1.0), $\nu_{max.}$ 2 725 and 1 725 $cm^{-1}$, δ 0.76 (3 H, s, 13-Me), 0.96 (3 H, s, 10-Me), 1.06 (3 H, s, 1β-Me), 2.02 (3 H, s, 2α- or 17β-OAc), 2.04 (3 H, s, 17β- or 2α-OAc), and 9.75 (1 H, s, 1α-CHO) (Found: C, 69.55; H, 8.75. $C_{24}H_{36}O_5 \cdot \frac{1}{2}H_2O$ requires C, 69.8; H, 9.05%), and a second fraction (635 mg), which by acetylation and further purification by p.l.c. [benzene–ether (95 : 5) as eluant, five runs] gave 1-*methylene*-5α-*androstane*-2α,3α,17β-*triol triacetate* (16) (410 mg), m.p. 132—133° (from hexane), $[\alpha]_D$ +63.6° (*c* 1.0), $\nu_{max.}$ 1 730 and 1 630 $cm^{-1}$, δ 0.80 (3 H, s, 13-Me), 1.01 (3 H, s, 10-Me), 2.00 (6 H, s, 2α- and 3α-OAc, 2α- and 17β-OAc, or 3α- and 17β-OAc), 2.02 (3 H, s, 2α-, 3α-, or 17β-OAc), 4.84 and 4.95br (2 H, $CH_2$=CH), 5.32br (1 H, 2β- or 3β-H), and 5.51br (1 H, 3β- or 2β-H) (Found: C, 69.8; H, 8.55. $C_{26}H_{38}O_6$ requires C, 69.9; H, 8.6%).

*Reduction of* 17β-*Acetoxy*-1α,2α-*epoxy*-1β-*methyl*-5α-*androstan*-3-*one* (1) *with Lithium Aluminium Hydride.*—A solution of the epoxide (1) (1 g) in dry ether (40 ml) was added slowly to a stirred suspension of lithium aluminium hydride (1 g) in dry ether (40 ml) and refluxed for 4 h. Ethyl acetate was cautiously added to the cooled mixture and then a small amount of water was poured into the reaction vessel. The ethereal solution was separated by filtration and the solid residue was washed with ether. The ethereal solution was washed with water, dried ($Na_2SO_4$), and evaporated. The crude residue (0.45 g) was acetylated (0.51 g) to be purified by chromatography on deactivated alumina (Brockman grade II) (25 g). Elution with benzene–ether (9 : 1 and 8 : 2) gave a product, which, after hydrolysis in 5% methanolic potassium hydroxide solution at room temperature overnight, afforded 1β-*methyl*-5α-*androstane*-1α,3α,17β-*triol* (17) (180 mg), m.p. 242—243° (from methanol), $[\alpha]_D$ +57° (*c* 1.0 $C_5H_5N$), $\nu_{max.}$ 3 320 $cm^{-1}$, δ ($C_5D_5N$) 0.83 (3 H, s, 13-Me), 0.94 (3 H, s, 10-Me), and 1.38 (3 H, s, 1β-Me) (Found: C, 74.2; H, 10.55. $C_{20}H_{34}O_3$ requires C, 74.5; H, 10.65%). The solid residue from the treatment with ether was extracted with ethyl acetate in a Soxhlet apparatus for 60 h to give 1β-*methyl*-5α-*androstane*-1α,3β,17β-*triol* (18) (0.44 g), m.p. 204—205° (from ethyl acetate), $[\alpha]_D$ +25° (*c* 0.75 methanol), $\nu_{max.}$ 3 500—3 200 $cm^{-1}$, δ ($C_5D_5N$) 0.96 (3 H, s, 13- or 10-Me), 0.98 (3 H, s, 10- or 13-Me), and 1.52 (3 H, s, 1β-Me) (Found: C, 70.7; H, 10.6. $C_{20}H_{34}O_3 \cdot H_2O$ requires C, 70.55; H, 10.65%).

1β-*Methyl*-5α-*androstane*-1α,3β,17β-*triol* 3,17-*Diacetate* (19).—Acetylation of the triol (18) (2.35 g) afforded the *diacetate* (19) (2.77 g), m.p. 145—147° (from hexane), $[\alpha]_D$ +20° (*c* 1.0), $\nu_{max.}$ 3 330 and 1 710 $cm^{-1}$, δ 0.76 (3 H, s, 13-Me), 0.88 (3 H, s, 10-Me), 1.35 (3 H, s, 1β-Me), 1.99 (3 H, s, 3β- or 17β-OAc), and 2.02 (3 H, s, 17β- or 3β-OAc) (Found: C, 70.95; H, 9.35. $C_{24}H_{38}O_5$ requires C, 70.9; H, 9.4%).

*Reaction of* 1β-*Methyl*-5α-*androstane*-1α,3β,17β-*triol* 3,17-*Diacetate* (19) *with Toluene*-p-*sulphonic Acid.*—The 1α-hydroxy-diacetate (19) (2.8 g) in acetic anhydride (45 ml) and acetic acid (45 ml) was treated with toluene-*p*-sulphonic acid (560 mg) at room temperature for 24 h. The solution was poured into brine and the usual work-up, after extraction with ether, ga a crude residue (2.9 g), which was chromatographed on deactivated alumina (Brockman grade II; 200 g). Elution with benzene and benzene–ether (95 : 5) gave 1-*methylene*-5α-*androstane*-3β,17β-*diol diacetate* (21) (800 mg), m.p. 106—107° (from hexane), $[\alpha]_D$ +78° (*c* 1.0), $\nu_{max.}$ 1 730 and 1 630 $cm^{-1}$, δ 0.83 (3 H, s, 13-Me), 0.98 (3 H, s, 10-Me), 2.02 (6 H, s, 3β- and 17β-OAc), 4.63 and 4.81br (2 H, $CH_2$=C) (Found: C, 74.0; H, 9.05. $C_{24}H_{36}O_4$ requires C, 74.2; H, 9.35%). Further elutions with benzene–ether (8 : 2 and 1 : 1) and ether gave 1β-*methyl*-5α-*androstane*-1α,3β,17β-*triol triacetate* (20) (1.7 g), m.p. 137—138° (from methanol–water), $[\alpha]_D$ 0° (*c* 2.0), $\nu_{max.}$ 1 730 and 1 715 $cm^{-1}$, δ 0.80 (3 H, s, 13-Me), 1.05 (3 H, s, 10-Me), 1.67 (3 H, s, 1β-Me), 1.95 (3 H, s, 1α-, 3β-, or 17β-OAc), 2.00 (3 H, s, 1α-, 3β-, or 17β-OAc), and 2.04 (3 H, s, 1α-, 3β-, or 17β-OAc) (Found: C, 69.6; H, 8.9. $C_{26}H_{40}O_6$ requires C, 69.6; H, 9.0%).

*Reduction of the Hydroxy-derivative* (6).—The hydroxy-derivative (6) (400 mg) in dry pyridine (5 ml) was treated with toluene-*p*-sulphonyl chloride (480 mg) at room temperature for 5 days. The mixture was poured into brine and extracted with ether and the usual work-up gave a residue (527 mg) which was dissolved in dry ether (40 ml) and added dropwise to a suspension of lithium aluminium hydride (250 mg) in dry ether (10 ml). The mixture was refluxed for 24 h. The product (300 mg) was isolated with ether, acetylated to give a residue (350 mg), and purified by p.l.c. (benzene–ether 95 : 5 as eluant) to give a *methylene diacetate* (237 mg) identical with compound (21).

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