Steroids. Part XVI.[1] Long-range Substituent Effects on Boron Trifluoride-catalysed Rearrangements of 5,6-Epoxy-steroids

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Highly electronegative substituents at either C-3 or C-17 in steroidal 5,6-epoxides suppress C-5 carbonium ion rearrangements in favour of fluorohydrin formation. The 6α,9α-epoxy-1(10 → 5)*abeo*-cholestane structures (37) and (38) are assigned to previously isolated compounds.

THE boron trifluoride-catalysed rearrangements of 5,6-epoxycholestanes are susceptible to changes in substituents at C-3 [2] and at C-19.[3] Although the effects of the variation of substituents at C-17 on a number of reactions have been widely reported,[4] no similar studies on 5,6-epoxide rearrangements are known. We report here that a change of the 3β-substituent in 5,6-epoxyandrostanes and -pregnanes from OAc to OH or OMe suppresses BF_3-catalysed C(5)–O cleavage, as in the 5,6-epoxycholestanes.[2a] Also, C(5)–O cleavage is suppressed by an increase in the $-I$ effect of substituents at C-17.

The 3β-methoxy-epoxides (3) and (7) were prepared by oxidation of 3β-methoxyandrost-5-en-17-one [5] and 3β-methoxypregn-5-en-20-one,[6] respectively, with monoperoxyphthalic acid. The Table summarises the product distributions from the reactions of solutions of the various epoxides in benzene with boron trifluoride–ether complex. The products were isolated by t.l.c. Acetylation of the crude or partially purified reaction mixture was required in a number of cases to effect a separation, and

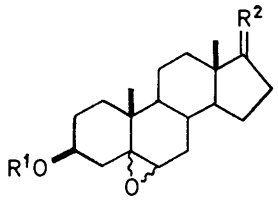
Products isolated from the reactions of epoxides with boron trifluoride–ether complex

Epoxide; % recovered	Fluorohydrin; % yield	Ketone; % yield	Δ⁹-Compound; % yield	Others; % yield
(1); 7	(10); 64 [a]		(23); 16	
(2); 2 †	(10); [a] 25 †	(17); 19 †	(23); 35	
(3); 4	(11); 13	(18); 21	(24); 18	
(4); 0	(15); 27	(19; [b] 15		(27); 5
(5); 13	(12); [c] 72		(25); 8	
(6); 0	(12); [c] 8	(20); 28	(25); 30	
(7); 0	(13); 7	(21); 14	(26); 20	(28); 3
				(29); 2
(8); 0	(16); 48	(22); 23		
(9); 0	(14); 41 [c]			

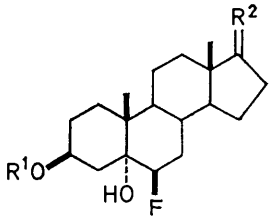
† Estimated by ^1H n.m.r.
[a] Ref. 9. [b] Ref. 15. [c] Ref. 27. [d] Ref. 28.

[1] Part XV, J. G. Ll. Jones and B. A. Marples, *J.C.S. Perkin I*, 1972, 792.
[2] (*a*) I. G. Guest and B. A. Marples, *J. Chem. Soc.* (*C*), 1970, 1626; (*b*) J. M. Coxon, M. P. Hartshorn, and B. L. S. Sutherland, *Tetrahedron Letters*, 1969, 4029 and previous papers in this series.
[3] I. G. Guest and B. A. Marples, *J. Chem. Soc.* (*C*), 1971, 576.
[4] (*a*) D. N. Kirk and M. P. Hartshorn, 'Steroid Reaction Mechanisms,' Elsevier, Amsterdam, 1968, p. 16; (*b*) R. T. Blickenstaff and K. Sophasan, *Tetrahedron*, 1972, **28**, 1945.
[5] A. Butenandt and W. Grosse, *Ber.*, 1936, **69**, 2776.
[6] A. Butenandt and W. Grosse, *Ber.*, 1937, **70**, 1446.

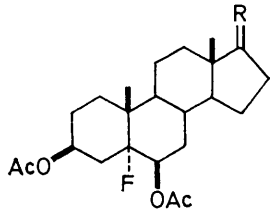
accounts for the isolation of the acetyl derivatives of the expected products.



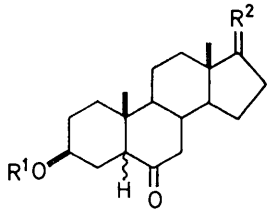
(1) 5α, 6α, R^1 = Ac, R^2 = O
(2) 5α, 6α, R^1 = H, R^2 = O
(3) 5α, 6α, R^1 = Me, R^2 = O
(4) 5β, 6β, R^1 = H, R^2 = O
(5) 5α, 6α, R^1 = Ac, R^2 = β-Ac, H
(6) 5α, 6α, R^1 = H, R^2 = β-Ac, H
(7) 5α, 6α, R^1 = Me, R^2 = β-Ac, H
(8) 5β, 6β, R^1 = H, R^2 = β-Ac, H
(9) 5α, 6α, R^1 = Ac, R^2 = β-C_8H_{17}, H



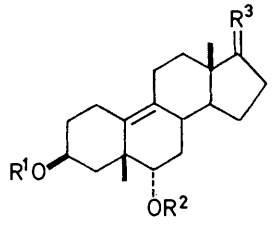
(10) R^1 = Ac, R^2 = O
(11) R^1 = Me, R^2 = O
(12) R^1 = Ac, R^2 = β-Ac, H
(13) R^1 = Me, R^2 = β-Ac, H
(14) R^1 = Ac, R^2 = β-C_8H_{17}, H



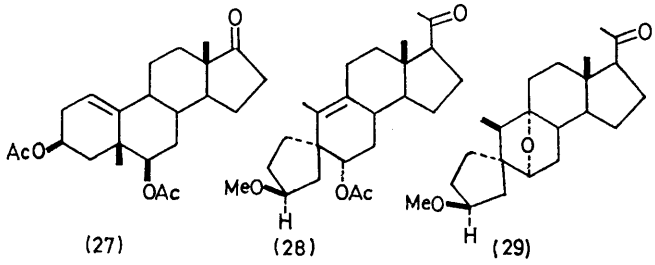
(15) R = O
(16) R = β-Ac, H



(17) R^1 = Ac, 5β, R^2 = O
(18) R^1 = Me, 5β, R^2 = O
(19) R^1 = H, 5α, R^2 = O
(20) R^1 = Ac, 5β, R^2 = β-Ac, H
(21) R^1 = Me, 5β, R^2 = β-Ac, H
(22) R^1 = Ac, 5α, R^2 = β-Ac, H



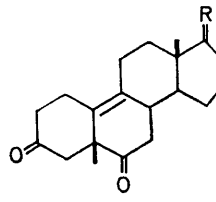
(23) R^1 = R^2 = Ac; R^3 = O
(24) R^1 = Me, R^2 = Ac, R^3 = O
(25) R^1 = R^2 = Ac, R^3 = β-Ac, H
(26) R^1 = Me, R^2 = Ac, R^3 = β-Ac, H



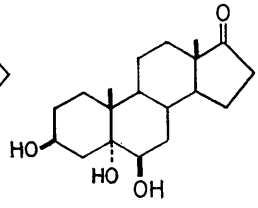
(27) (28) (29)

Epoxides of the Androstane Series.—*3β-Acetoxy-5α,6α-epoxide* (1).[7] The reaction between the 5α,6α-epoxide (1) and boron trifluoride–ether complex in benzene [8] has been used by us as a preparative route to the fluorohydrin (10).[9] However, we did not previously investigate the other products of this reaction. The Δ^9-compound (23) was identified from its ^{1}H n.m.r. spectrum, which showed characteristic signals for the 5β-methyl group (τ 8·76) [10] and the 6β-H [τ 5·32, q, *J*(apparent) *ca.* 11 and 4 Hz].[11] Further confirmation for the structure (23) was obtained from its u.v. spectrum (ε_{215} 5380) [12] and its conversion into the known triketone (30) [13] by successive hydrolysis and oxidation.

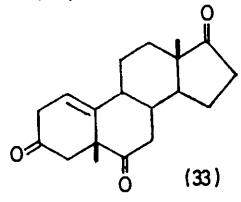
3β-Hydroxy-5α,6α-epoxide (2).[7] The Δ^9-compound (23) was separated from a mixture of the fluorohydrin (10), the 5β-6-ketone (17), and the 5α,6α-epoxide (1). Although this latter mixture could not be satisfactorily resolved by t.l.c., it was possible to isolate a small quantity of the fluorohydrin (10), and the composition of the mixture was determined from the integrated intensities of the characteristic methine proton n.m.r.



(30) R = O
(31) R = β-Ac, H



(32)



(33)

signals of the three components. Successive treatment of the mixture with base and periodic acid in acetone [14] led to the isolation of the 5α-6-ketone (19),[15] and the 3β,5α,6β-triol (32).[16] The former arises from epimerisation and hydrolysis of the ketone (17); the latter arises from hydrolysis of the 5α,6α-epoxide (1) and the 5β,6β-epoxide (4) which is formed from the fluorohydrin (10).

3β-Methoxy-5α,6α-epoxide (3). The fluorohydrin (11) was identified from its ^{1}H n.m.r. spectrum, which showed characteristic doublets for the 10-methyl group (τ 8·87,

[7] M. Ehrenstein, *J. Org. Chem.*, 1941, **6**, 626.
[8] I. G. Guest, J. G. Ll. Jones, B. A. Marples, and M. J. Harrington, *J. Chem. Soc.* (*C*), 1969, 2360.
[9] M. Mousseron-Canet and J.-C. Brial, *Bull. Soc. chim. France*, 1966, 3867.
[10] A. Fischer, M. J. Hardman, M. P. Hartshorn, D. N. Kirk, and A. R. Thawley, *Tetrahedron*, 1967, **23**, 159.
[11] J.-C. Guilleux and M. Mousseron-Canet, *Bull. Soc. chim. France*, 1967, 24.
[12] L. Dorfman, *Chem. Rev.*, 1953, **53**, 47.
[13] M. Davis and V. A. Petrow, *J. Chem. Soc.*, 1949, 2973.
[14] L. F. Fieser and S. Rajagopalan, *J. Amer. Chem. Soc.*, 1949, **71**, 3938.
[15] H. B. Macphillamy and C. R. Scholz, *J. Amer. Chem. Soc.*, 1952, **74**, 5512.
[16] N. D. Zelinski and M. I. Ushakov, *Bull. Acad. Sci. U.S.S.R.*, 1936, 879 (*Chem. Abs.*, 1937, **31**, 5373).

J ca. 5 Hz) and the 6-H (τ 5·71, *J ca.* 50 Hz).[17] The i.r. spectrum confirmed the presence of the 5α-hydroxy-group ($\nu_{max.}$ 3610 and 3400 cm^{-1}). The Δ^9-compound (24) had a similar ^1H n.m.r. spectrum to that of compound (23) and intense end absorption in the u.v. spectrum (ε_{215} 4600) confirmed the presence of the 9,10-double bond.[12] The ketone (18) was identified from its i.r. spectrum ($\nu_{max.}$ 1750 and 1715 cm^{-1}) and the 3-H signal in the ^1H n.m.r. spectrum confirmed the *cis* A/B ring junction (τ 6·59, $W_{\frac{1}{2}}$ *ca.* 8 Hz).

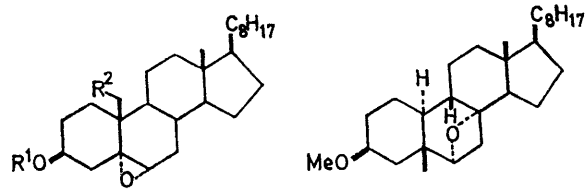
3β-*Hydroxy*-5β,6β-*epoxide* (4).[7] The presence of the tertiary fluorine atom in the fluorohydrin (15) was indicated by the mass spectrum, which showed peaks at *m/e* 328 and 268 corresponding to the loss of HF from the fragment ions *m/e* 348 and 288, which arise by loss of one and two molecules, respectively, of acetic acid from the parent ion (*m/e* 408). Additional evidence in support of the structure (15) was afforded by its conversion into the 5β,6β-epoxide (4) by treatment with base. The structure of the $\Delta^{1(10)}$ compound (27) was essentially assigned from the chemical shifts for the 5-methyl group (τ 8·75), the 13-methyl group (τ 9·11), and the 1-H (τ 4·67).[10,18] Successive hydrolysis and oxidation of the $\Delta^{1(10)}$ compound (27) gave the olefinic triketone (33) ($\nu_{max.}$ 1745 and 1720 cm^{-1}). Attempted base-catalysed isomerisation of this olefinic triketone (33) to the Δ^1-3,6,17-triketone gave a mixture of products which was not further investigated.

Epoxides of the Pregnane Series.—3β-*Acetoxy*-5α,6α-*epoxide* (5).[7] The Δ^9-compound (25) was readily identified from its ^1H n.m.r.[10,11] and u.v. spectra,[12] which were similar to those of compound (23), and from its conversion into the known triketone (31).[19]

3β-*Hydroxy*-5α,6α-*epoxide* (6).[7] The structure of the 5β-6-ketone (20) was confirmed by the absence of a 6-H signal and the narrow band width of the 3-H signal (τ 5·02, $W_{\frac{1}{2}}$ *ca.* 8 Hz) in the ^1H n.m.r. spectrum.

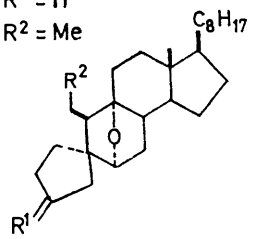
3β-*Methoxy*-5α,6α-*epoxide* (7). The Δ^9-compound (26), the fluorohydrin (13), and the 5β-6-ketone (21) all had spectral data in close agreement with those of their androstane analogues. The u.v. spectrum of the spiro-compound (28) (ε_{215} 6520) indicated the presence of a tetrasubstituted double bond.[12] The 10-methyl signal appeared as a broad singlet (τ 8·32) in the ^1H n.m.r. spectrum owing to homoallylic coupling, and the 13-methyl group (τ 9·31) and the 6β-H [τ 5·33 *J* (apparent) *ca.* 11 and 4 Hz] signals, being similar to those for the Δ^9-compound (26), appear to confirm the 9,10-position of the double bond. Retention of configuration at C-5 is assumed from mechanistic considerations (see Discussion section). The i.r. spectrum of the 6α,9α-epoxy-spiro-compound (29) showed no OH absorption and the C(20)=O absorption at 1728 cm^{-1}. The 6-H and the 10-methyl group appeared as doublets in the ^1H n.m.r. spectrum [τ 6·17 (*J ca.* 6 Hz) and 9·15 (*J ca.* 7 Hz), respectively]. Models suggest that in the compound (29) the 6-H would be spin–spin coupled only to the 7β-H, as the torsion angle between it and the 7α-H is *ca.* 90°. Irradiation at τ 8·5 caused the methyl doublet to collapse to a singlet and located the chemical shift of the 10-H. As in the case of the spiro-compound (28), retention of configuration at C-5 and the 10α-H configuration are assumed (see Discussion section).

We have previously reported that boron trifluoride-catalysed cleavage of the 3β-methoxy-5α,6α-epoxide (34) gave the ether (35),[2a] and that the 19-methyl-5α,6α-epoxide (36) under similar conditions gave a small amount of an ether which was not fully characterised.[3] By analogy with the 6α,9α-epoxy-spiro-compound (29), we now suggest that the structure (35) should be amended to (37), and that the ether obtained from the compound (36) has the structure (38). Each of the 6-H signals in the ^1H n.m.r. spectra of 6α,9α-epoxy-spiro-compounds (37) and (38) appears as a doublet (*J ca.* 5—6 Hz) at τ 9·33.[2a,3] In the 60 MHz spectrum of compound (37) the 10-methyl signal is not resolved from the side chain methyl signals. However, a 220 MHz spectrum shows the 10-methyl doublet at 9·09 (*J ca.* 7·5 Hz). Further evidence for the spiro-structure (37) was obtained by its conversion into the $\Delta^{13(17)}$-diketone (41) by



(34) R^1 = Me, R^2 = H
(36) R^1 = Ac, R^2 = Me

(35)



(37) R^1 = β-MeO,H, R^2 = H
(38) R^1 = β-AcO,H, R^2 = Me
(39) R^1 = β-OH,H, R^2 = Me
(40) R^1 = O, R^2 = Me

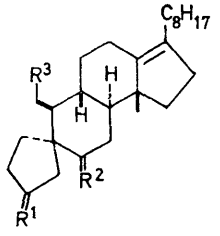
treatment with boron trifluoride–ether complex in acetic anhydride–acetic acid, followed by successive hydrolysis and oxidation. The diketone (41) showed characteristic carbonyl bands in the i.r. spectrum ($\nu_{max.}$ 1750 and 1715 cm^{-1}). The ^1H n.m.r. spectrum, which showed the 14β-methyl group signal (τ 9·08) superimposed on the high-field branch of the 20-methyl doublet (τ 9·04, *J ca.* 5 Hz), was characteristic of $\Delta^{13(17)}$-compounds, and irradiation 83 Hz downfield from the 20-methyl doublet caused its collapse to a shoulder

[17] N. S. Bhacca and D. H. Williams, ' Applications of N.M.R. Spectroscopy in Organic Chemistry,' Holden-Day, San Francisco, 1964, p. 123.

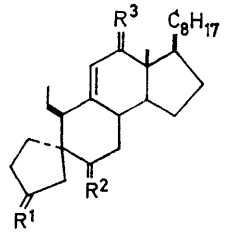
[18] Ref. 17, p. 21.

[19] P. Brown, O. R. Rodig, and P. Zaffaroni, *J. Org. Chem.* 1961, **26**, 2431.

on the 14β-methyl group signal.[20] In addition, the base peak (*m/e* 285) in the mass spectrum of compound (41) characteristically corresponded to the loss of the side chain from the parent ion.[21] The reaction of compound (37) with boron trifluoride in acetic anhydride presumably involves the preferential cleavage of the C(9)–O and the C(3)–O bonds. The C-3 carbonium ion thus formed is captured by acetate ion and the C-9 carbonium rearranges in typical fashion to give the 13,17-olefin. The 6α,9α-epoxy-spiro-compound (38) was similarly converted, *via* the diacetate (42) and the diol (43), into the diketone (44), which had similar spectral data to compound (41). Additional evidence in support of the spiro-structure (38) was obtained by its conversion into the cyclopentanone (40) ($\nu_{max.}$ 1740 cm^{-1}) *via* the alcohol (39). The ^1H n.m.r. spectrum of the cyclopentanone (40) showed the characteristic doublet for the 6-H (τ 6·1, *J ca.* 6 Hz).



(41) $R^1 = R^2 = O$, $R^3 = H$
(42) $R^1 = \beta$-AcO,H, $R^2 = \alpha$-AcO,H, $R^3 = Me$
(43) $R^1 = \beta$-OH,H, $R^2 = \alpha$-OH,H, $R^3 = Me$
(44) $R^1 = R^2 = O$, $R^3 = Me$



(45) $R^1 = \beta$-AcO,H, $R^2 = \alpha$-AcO,H, $R^3 = H_2$
(46) $R^1 = \beta$-OH,H, $R^2 = \alpha$-OH,H; $R^3 = H_2$
(47) $R^1 = R^2 = O$, $R^3 = H_2$
(48) $R^1 = \beta$-AcO,H, $R^2 = \alpha$-AcO,H, $R^3 = O$

Although these data clearly demonstrate that the spiro-structure is present in compounds (37) and (38), they do not completely exclude the possibility of a 6,8-oxetan structure. However, the 6α,9α-epoxy-3β-hydroxy- (39) spiro-compound was shown to be unreactive towards both lithium aluminium hydride and lithium in ethylamine. Also, the reaction of compound (39) with boron trifluoride–ether complex in acetic anhydride–acetic acid gave the expected $\Delta^{13(17)}$-compound (42) and the $\Delta^{9(11)}$-compound (45). The isolation of the latter, presumably by loss of a proton from C-11 in the derived C-9 carbonium ion, supports the 6,9-epoxide structure (39). The trapping of the C-9 carbonium ion by the added acetic acid was expected by analogy with other work.[1,22] The ^1H n.m.r. spectrum of compound (45) clearly showed an olefinic proton signal at τ 4·73 and a relatively high field (τ 9·39) signal for the 13-methyl group, and thus supported the assigned structure.[18] Further evidence was obtained by conversion of the $\Delta^{9(11)}$-compound (45) *via* the diol (46) into the diketone (47) ($\nu_{max.}$ 1755 and 1715 cm^{-1}). The absence of conjugated enone absorption confirmed the 9,11-position for the double bond rather than the alternative 7,8-position. Allylic oxidation of the compound (45) with *N*-bromosuccinimide in aqueous dioxan[23] gave the conjugated enone (48) ($\nu_{max.}$ 1685 cm^{-1}; $\lambda_{max.}$ 237 nm). The downfield position of the 13-methyl signal (τ 9·18) in the 100 MHz ^1H n.m.r. spectrum of compound (48) relative to that in compound (45) is compatible with the introduction of a 12-oxo-group.[18] The olefinic proton signal appears as a doublet (*J ca.* 2 Hz) owing to allylic coupling with the 8β-H. The torsion angle between the 8β-H and the plane of the olefinic bond is *ca.* 90°, as is required for allylic coupling,[24] and the absence of any other coupling suggests the 10α-H configuration.

3β-*Hydroxy*-5β,6β-*epoxide* (8). The fluorohydrin (16) was readily identified from its spectral data, which were similar to those for the fluorohydrin (15).

DISCUSSION

It is generally agreed that boron trifluoride-catalysed backbone-type rearrangements of epoxides proceed essentially *via* a series of carbonium ions, though in certain cases some degree of concertedness is apparent.[1] With the exception of the fluorohydrins, which are formed by attack of fluoride on the boron trifluoride–epoxide complex, all the products could be derived from initially formed C-5 carbonium ions. The rearrangement of the C-5 carbonium ion derived from the 3β-methoxy-5α,6α-epoxide (7) to give the spiro-compounds (28) and (29) is worthy of special comment. Owing to the requirement for efficient overlap of the orbital of the migrating group with the empty orbital of the carbonium ion, it seems likely that the migration of the C(1)–C(10) bond takes place across the α-face of the molecule, resulting in retention of configuration at C-5.[25] The resultant C-10 carbonium ion may lose a proton from C-9 to give the spiro-compound (28). Alternatively, a hydride ion shift from C-9 to C-10 and capture of the resultant C-9 carbonium ion by the 6α-oxygen atom would give the 6α,9α-epoxy-spiro-compound (29). Such a mechanism would result in the 10α-H configuration for compound (29). We have already presented evidence

[20] J. W. Blunt, M. P. Hartshorn, and D. N. Kirk, *Tetrahedron*, 1966, **22**, 3195.
[21] (*a*) G. Snatzke and H.-W. Fehlhaber, *Annalen*, 1964, **676**, 188; (*b*) J. W. Blunt, M. P. Hartshorn, and D. N. Kirk, *Tetrahedron Letters*, 1966, 2125.
[22] J. M. Coxon, M. P. Hartshorn, G. A. Lane, K. E. Richards, and U. Senanayake, *Steroids*, 1969, **14**, 441.
[23] B. W. Finucane and J. B. Thompson, *Chem. Comm.*, 1969, 1220.
[24] Ref. 17, p. 108.
[25] J. M. Coxon, M. P. Hartshorn, and C. N. Muir, *Chem. Comm.*, 1970, 1591.

in support of this configuration for the analogous compound (38), and we suggest that the 6α,9α-epoxy-spiro-compounds (29), (37), and (38) are each formed by the same mechanism, and accordingly have the 10α-H configuration.

It is apparent from the Table that for the 5α,6α-epoxides the replacement of the 3β-OAc substituent by -OH or -OMe results in a reduced yield of the corresponding fluorohydrin. These trends for the androstane and pregnane derivatives are in agreement with that observed for a similar series of cholestane derivatives,[2a] and support the view that the $-I$ effect of the 3β-substituent * is critical in determining the reaction course. The 3β-OAc group markedly inhibits C(5)–O cleavage and allows attack by fluoride at C-6 to compete effectively. The reduced $-I$ effect of the -OH and particularly the -OMe groups allows more typical trisubstituted epoxide behaviour and most of the products are derived from the C-5 carbonium ions.

For a given 3β-substituent, the androstane and pregnane series of 5α,6α-epoxides give higher yields of the appropriate fluorohydrins than are obtained in the cholestane series [2a] (Table) (*cf.* ref. 20). This can be partly attributed to the increased $-I$ effects of the polar C-17 substituents * which would destabilise the build-up of positive charge at C-5 which is involved in C(5)–O cleavage. A similar effect is apparent in the reactions of the 5β,6β-epoxides (4) and (8), which give high yields of the fluorohydrins (15) and (16), respectively, in contrast to the reactions of 5,6β-epoxy-5β-cholestan-3β-ol [2a] which gave only products derived from C(5)–O cleavage. Similar long-range inductive effects have been reported previously.[4] However, the curiously high yields of the fluorohydrins (12) and (16) (Table) suggest that there could be other factors also operating. A more quantitative approach will be necessary to determine the precise function of the C-17 substituents.

EXPERIMENTAL

Solutions were dried over anhydrous sodium sulphate and solvents were removed *in vacuo* on a rotary evaporator. Plates (1 m × 0·5 mm thick) of Kieselgel PF 254 (Merck) were used for preparative t.l.c.

I.r. spectra were determined with Perkin-Elmer 237 and 257 spectrophotometers. U.v. spectra were determined for solutions in hexane, unless specified otherwise, with Unicam SP 800 and Uvispek spectrophotometers. ^{1}H N.m.r. spectra were determined, for solutions in carbon tetrachloride, unless specified otherwise, at 60 MHz with a Perkin-Elmer R10 spectrometer, at 100 MHz with a Varian HA100 spectrometer, or at 220 MHz with a Varian HR220 spectrometer. Mass spectra were recorded with A.E.I. MS 902 and MS 12 spectrometers. Rotations were measured for solutions in chloroform at 22° with a Bendix polarimeter 143C.

5,6α-Epoxy-3β-methoxy-5α-androstan-17-one (3).—3β-Methoxyandrost-5-en-17-one (3·0 g) was left to dissolve in a solution (175 ml) of monoperoxyphthalic acid in ether (60 g l^{-1}) and set aside at room temperature overnight. The excess of acid was removed by washing the solution with 2N-sodium hydroxide and water; drying and evaporation then gave the *epoxide* (3) (3·0 g), m.p. 167—169° (from methanol), $[\alpha]_D$ −18·5° (*c* 0·6), $\nu_{max.}$ (CCl_4) 2830, 1095 (OMe), and 1735 (C=O) cm^{-1}, τ ($CDCl_3$) 6·6—6·95 (m, 3-H), 6·69 (s, OMe), 7·07 (d, *J ca.* 4 Hz, 6-H), 8·93 (s, 10β-Me), and 9·19 (s, 13β-Me) (Found: C, 75·25; H, 9·3. $C_{20}H_{30}O_3$ requires C, 75·45; H, 9·5%).

5,6α-Epoxy-3β-methoxy-5α-pregnan-20-one (7).—3β-Methoxypregn-5-en-20-one (2·5 g) was similarly oxidised to the *epoxide* (7) (2·5 g), m.p. 146—148° (from ethyl acetate), $[\alpha]_D$ 0° (*c* 0·67), $\nu_{max.}$ (CCl_4) 2830, 1095 (OMe), and 1708 (C=O) cm^{-1}, τ 6·55—7·00 (m, 3-H), 6·80 (s, OMe), 7·25 (d, *J ca.* 4 Hz, 6-H), 8·06 (s, MeCO), 8·99 (s, 10β-Me), and 9·49 (s, 13β-Me) (Found: C, 76·2; H, 9·8. $C_{22}H_{34}O_3$ requires C, 76·25; H, 9·9%).

Reactions of Epoxides with Boron Trifluoride–Ether Complex.—The epoxide, dissolved in sodium-dried benzene (5% w/v), was treated with BF_3,Et_2O (1 ml per g of steroid) for the specified time at room temperature. The mixture was poured into a saturated solution of sodium hydrogen carbonate and extracted with ether. The extract was washed with water, dried, and evaporated to give the crude product mixture.

Reaction of 3β-Acetoxy-5,6α-epoxy-5α-androstan-17-one (1).—The epoxide (1) (1·2 g) was treated with BF_3,Et_2O for 5 min. Preparative t.l.c. of the crude product [ethyl acetate–benzene (1 : 3) as eluant] gave 3β-acetoxy-6β-fluoro-5-hydroxy-5α-androstan-17-one (10) (812 mg), m.p. 165—166° (from methanol), $[\alpha]_D$ +24° (*c* 1·0), $\nu_{max.}$ ($CDCl_3$) 3620 and 3450 (OH), and 1740 (C=O) cm^{-1}, τ ($CDCl_3$) 4·90 (m, $W_{\frac{1}{2}}$ *ca.* 20 Hz, 3-H), 5·71 (d, J_{HF} *ca.* 50 Hz, 6-H), 8·00 (s, OAc), 8·90 (d, *J ca.* 5 Hz, 10β-Me), and 9·13 (s, 13β-Me) {lit.,[9] m.p. 159—161°, $[\alpha]_D$ +15·6° (dioxan)}, the epoxide (1) (78 mg), and a polar fraction. Acetylation of the last fraction (excess of acetic anhydride–pyridine at room temperature; standard work-up) gave, after further t.l.c., *3β,6α-diacetoxy-5-methyl-19-nor-5β-androst-9-en-17-one* (23) (211 mg), a gum, $[\alpha]_D$ +94° (*c* 0·85), ε_{215} 5380, $\nu_{max.}$ ($CDCl_3$) 1735 (C=O) cm^{-1}, τ ($CDCl_3$) 4·86 (m, $W_{\frac{1}{2}}$ *ca.* 10 Hz, 3-H), 5·32 [q, *J* (apparent) *ca.* 11 and 4 Hz, 6-H], 7·95 (s, 2 × OAc), 8·76 (s, 5β-Me), and 9·03 (s, 13β-Me) (Found: C, 70·9; H, 8·4. $C_{23}H_{32}O_5$ requires C, 71·1; H, 8·3%).

5-Methyl-19-nor-5β-androst-9-ene-3,6,17-trione (30).—A solution of the diacetate (23) in aqueous methanolic potassium hydroxide (5%) was heated under reflux for 30 min. After normal work-up, the crude product was dissolved in acetone and oxidised with an excess of Jones reagent [26] for 5 min at 0°. The usual work-up gave the triketone (30), m.p. 175—176° [from benzene–light petroleum (b.p. 60—80°)], $\nu_{max.}$ (CCl_4) 1740 [C(17)=O] and 1718 [C(3)=O, C(6)=O] cm^{-1} (lit.,[13] m.p. 175—177°).

Reaction of 5,6α-Epoxy-3β-hydroxy-5α-androstan-17-one (2).—The epoxide (2) (600 mg) was treated in a saturated solution (*ca.* 1·2%) with BF_3,Et_2O for 7 min. Acetylation of the crude product in the usual manner, followed by preparative t.l.c. [ethyl acetate–benzene (1 : 3)] gave the Δ^9-compound (23) (244 mg) and an inseparable mixture of three product (455 mg). The composition of the mixture was determined from the integrated areas of the 3- and 6-methine protons (see earlier). Further preparative t.l.c. of the mixture (100 mg) in ethyl acetate–benzene (1 : 1) on silver nitrate-impregnated plates (10%) allowed the isolation of the fluorohydrin (10) (30 mg). Hydrolysis of the mixture

* Presumably co-ordinated with BF_3.

[26] C. Djerassi, R. R. Engle, and A. Bowers, *J. Org. Chem.*, 1956, **21**, 1547.

(200 mg), as before, gave a crude product which was dissolved in a solution of periodic acid (100 mg) in acetone–water (15 ml; 9 : 1) and heated under reflux for 0·5 h. Dilution with water and extraction with ether afforded a mixture (160 mg) which was separated by t.l.c. [two elutions in ethyl acetate–benzene (1 : 1)] to give the ketone (19) (49 mg), m.p. 205—207° (from methanol), $[\alpha]_D$ +30° (*c* 0·35) (lit.,[15] m.p. 204—207°, $[\alpha]_D$ +33°), and the triol (32) (80 mg), m.p. 296—298° (from acetone) (lit.,[16] m.p. 301—302°).

Reaction of 5,6α-*Epoxy*-3β-*methoxy*-5α-*androstan*-17-*one* (3).—The epoxide (3) (2·0 g) was treated with BF_3,Et_2O for 5 min. Preparative t.l.c. in ethyl acetate–benzene (1 : 1) gave two main fractions which were acetylated in the usual manner. Further t.l.c. of these fractions in benzene–ethyl acetate (10 : 1) gave 6α-*acetoxy*-3β-*methoxy*-5-*methyl*-19-*nor*-5β-*androst*-9-*en*-17-*one* (24) (400 mg), m.p. 151—152° (from methanol), $[\alpha]_D$ +136° (*c* 0·76), ε_{215} 4600, $\nu_{max.}$ (CCl_4) 2830, 1090 (OMe), and 1745 (C=O) cm^{-1}, τ ($CDCl_3$) 5·33 [q, *J* (apparent) *ca.* 10 and 4 Hz, 6-H], 6·47 (m, $W_{\frac{1}{2}}$ *ca.* 12 Hz, 3-H), 6·71 (s, OMe), 7·98 (s, OAc), 8·76 (s, 5β-Me), and 9·04 (s, 13β-Me) (Found: C, 72·85; H, 8·85. $C_{22}H_{32}O_4$ requires C, 73·3; H, 8·95%), 6β-*fluoro*-5-*hydroxy*-3β-*methoxy*-5α-*androstan*-17-*one* (11) (269 mg), m.p. 223—225° (from methanol), $[\alpha]_D$ +42° (*c* 0·75), $\nu_{max.}$ ($CHCl_3$) 3610 and 3440 (OH), 2830, 1095 (OMe), and 1740 (C=O) cm^{-1}, τ ($CDCl_3$) 5·71 (d, J_{HF} *ca.* 50 Hz, 6-H), 6·40 (m, $W_{\frac{1}{2}}$ *ca.* 22 Hz, 3-H), 6·67 (s, OMe), 8·87 (d, J_{HF} *ca.* 5 Hz, 10β-Me), and 9·12 (s, 13β-Me) (Found: C, 71·35; H, 9·05. $C_{20}H_{31}FO_3$ requires C, 71·0; H, 9·25), 3β-*methoxy*-5β-*androstane*-6,17-*dione* (18) (414 mg), m.p. 163—164° (from methanol), $[\alpha]_D$ +6·7° (*c* 0·76), $\nu_{max.}$ (CCl_4) 2830, 1095 (OMe), 1750 [C(17)=O] and 1715 [C(6)=O] cm^{-1}, τ 6·59 (m, $W_{\frac{1}{2}}$ *ca.* 8 Hz, 3-H), 6·78 (s, OMe), and 9·14 (s, 10β, 13β-Me) (Found: C, 75·1; H, 9·4. $C_{20}H_{30}O_3$ requires C, 75·45; H, 9·5%), and the epoxide (3) (85 mg).

Reaction of 5,6β-*Epoxy*-3β-*hydroxy*-5β-*androstan*-17-*one* (4).—The epoxide (4) (600 mg) was treated in a saturated solution (*ca.* 1%) with BF_3,Et_2O for 7 min. Preparative t.l.c. of the crude product, in ethyl acetate–benzene (1 : 1), gave three fractions, one of which was a polar inseparable mixture (120 mg). The less polar of the remaining two fractions was subjected to further t.l.c., in chloroform–methanol (19 : 1), and gave 3β-hydroxy-5α-androstane-6,17-dione (19) [15] (91 mg), $\nu_{max.}$ ($CHCl_3$) 3610 and 3460 (OH), 1740 [C(17)=O] and 1715 [C(6)=O] cm^{-1}, τ ($CDCl_3$) 6·42 (m, $W_{\frac{1}{2}}$ *ca.* 24 Hz, 3-H), 9·12 (s, 10β-Me), and 9·22 (s, 13β-Me), and a second fraction, which after acetylation in the normal manner and crystallisation gave 3β,6β-*diacetoxy*-5-*fluoro*-5α-*androstan*-17-*one* (15) (217 mg), m.p. 247—248° (from methanol), $[\alpha]_D$ +7·1° (*c* 0·71), τ ($CDCl_3$) 4·60—5·40 (m, 3- and 6-H), 7·91 (s, OAc), 7·99 (s, OAc), 8·82 (s, 10β-Me), and 9·10 (s, 13β-Me) (Found: C, 67·8; H, 8·25. $C_{23}H_{33}FO_5$ requires C, 67·65; H, 8·15%). The remaining fraction was acetylated in the normal manner, and after further t.l.c., in ether–light petroleum (b.p. 60—80°) (1 : 1), gave 3β,6β-*diacetoxy*-5-*methyl*-19-*nor*-5β-*androst*-1(10)-*en*-17-*one* (27) (39 mg), m.p. 220—222° (from methanol), $[\alpha]_D$ +16° (*c* 0·31), $\nu_{max.}$ ($CHCl_3$) 1735 (C=O) cm^{-1}, τ ($CDCl_3$) 4·56—5·30 (m, 1-, 3-, and 6-H), 7·92 (s, OAc), 7·98 (s, OAc), 8·75 (s, 5β-Me), and 9·11 (s, 13β-Me) (Found: C, 71·1; H, 8·35. $C_{23}H_{32}O_5$ requires C, 71·1; H, 8·3%).

Treatment of the Fluorohydrin (15) *with Base.*—The fluorohydrin (100 mg) was heated under reflux in methanolic potassium hydroxide (5%; 10 ml) for 30 min and poured into water. Extraction with ether in the usual way gave the epoxide (4) (71 mg), identical with an authentic sample.

5-*Methyl*-19-*nor*-5β-*androst*-1(10)-*ene*-3,6,17-*trione* (33).—The diacetate (27) was hydrolysed and oxidised as for (23) and gave the triketone (33), a gum, $\nu_{max.}$ 1745 [C(17)=O] and 1720 [C(3)=O, C(6)=O] cm^{-1}, τ 4·5 (m, $W_{\frac{1}{2}}$ *ca.* 12 Hz, 1-H), 8·76 (s, 5β-Me), and 9·12 (s, 13β-Me).

Attempted Base-catalysed Isomerisation of the Triketone (33).—The triketone (33) (12 mg) in ethanol (0·6 ml) was heated under reflux for 1 h with ethanolic potassium hydroxide (0·1 ml; 30%). Normal work-up gave a mixture (t.l.c.) which was not further investigated.

Reaction of 3β-*Acetoxy*-5,6α-*epoxy*-5α-*pregnan*-20-*one* (5).—The epoxide (5) (1·65 g) was treated with BF_3,Et_2O for 10 min. The crude product was separated by t.l.c., in ethyl acetate–benzene (1 : 3), and gave 3β-acetoxy-6β-fluoro-5-hydroxy-5α-pregnan-20-one (12) (1·26 g), m.p. 222—224° (from methanol), $[\alpha]_D$ +43° (*c* 0·38), τ ($CDCl_3$) 4·90 (m, $W_{\frac{1}{2}}$ *ca.* 22 Hz, 3-H), 5·78 (d, J_{HF} *ca.* 50 Hz, 6-H), 7·90 and 8·00 (s, 20-Me and OAc), 9·11 (d, J_{HF} *ca.* 4 Hz, 10β-Me), and 9·39 (s, 13β-Me) (lit.,[27] m.p. 223—224°, $[\alpha]_D$ +42°), the epoxide (5) (218 mg), and a further polar fraction. Acetylation of this last fraction in the normal manner, and preparative t.l.c. of the crude product, in ethyl acetate–benzene (1 : 19), gave 3β,6α-*diacetoxy*-5-*methyl*-19-*nor*-5β-*pregn*-9-*en*-20-*one* (25) (140 mg), m.p. 118—119° (from methanol), $[\alpha]_D$ +136° (*c* 0·5), ε_{215} 5350, $\nu_{max.}$ (CCl_4) 1740 (acetate C=O) and 1712 [C(20)=O] cm^{-1}, τ ($CDCl_3$) 4·98 (m, $W_{\frac{1}{2}}$ *ca.* 10 Hz, 3-H), 5·44 [q, *J* (apparent) *ca.* 11 and 4 Hz, 6-H], 7·99 (m, 3- and 6-OAc, and 20-Me), 8·80 (s, 5β-Me), and 9·29 (s, 13β-Me) (Found: C, 71·85; H, 8·9. $C_{25}H_{36}O_5$ requires C, 72·1; H, 8·7%).

5-*Methyl*-19-*nor*-5β-*pregn*-9-*ene*-3,6,20-*trione* (31).—The diacetate (25) (100 mg) on hydrolysis and oxidation in the usual manner gave the triketone (31) (50 mg), m.p. 168—169° (from ethanol), $[\alpha]_D$ +6° (*c* 0·8) (lit.,[19] m.p. 167—169°, $[\alpha]_D$ +7·8°).

Reaction of 5,6α-*Epoxy*-3β-*hydroxy*-5α-*pregnan*-20-*one* (6).—The epoxide (6) (1·4 g) was treated with BF_3,Et_2O for 7 min. Acetylation of the crude product and preparative t.l.c., in benzene–ethyl acetate (3 : 1), gave a polar fraction (490 mg) which was not further investigated, and two further fractions which were subjected to t.l.c., in benzene–ethyl acetate (10 : 1), and gave the fluorohydrin (12) (129 mg), 3β-*acetoxy*-5β-*pregnane*-6,20-*dione* (20) (439 mg), m.p. 111—112° [from light petroleum (b.p. 60—80°)], $[\alpha]_D$ +13·8° (*c* 0·72), $\nu_{max.}$ (CCl_4) 1740 (acetate C=O) and 1710 [C(6)=O, C(20)=O] cm^{-1}, τ 5·02 (m, $W_{\frac{1}{2}}$ *ca.* 8 Hz, 3-H), 7·99 and 8·01 (s, 3-OAc and 20-Me), 9·14 (s, 10β-Me), and 9·44 (s, 13β-Me) (Found: C, 73·85; H, 9·20. $C_{23}H_{34}O_4$ requires C, 73·75; H, 9·15%), and the Δ^9-compound (25) (517 mg).

Reaction of 5,6α-*Epoxy*-3β-*methoxy*-5α-*pregnan*-20-*one* (7).—The epoxide (7) (3·0 g) was treated with BF_3,Et_2O for 5 min. Preparative t.l.c. of the crude product in benzene–ethyl acetate (10 : 1) gave two fractions. The more polar of these was subjected to further t.l.c., in ether–light petroleum (b.p. 60—80°) (3 : 2), after which the fractions were acetylated and further purified by t.l.c. to give 6α-*acetoxy*-3β-*methoxy*-5-*methyl*-19-*nor*-5β-*pregn*-9-*en*-20-*one* (26) (680 mg), a gum, $[\alpha]_D$ +97° (*c* 0·7), ε_{215} 5200, $\nu_{max.}$ (CCl_4) 2820, 1090 (OMe), 1730 (acetate C=O), and 1705 [C(20)=O]$^{-1}$, τ 5·47 [q, *J* (apparent) *ca.* 11 and 4 Hz, 6-H], 6·52 (m, $W_{\frac{1}{2}}$ *ca.* 11 Hz, 3-H), 6·76 (s, OMe), 8·00 and 8·04 (s, OAc and 20-Me), 8·81 (s, 5β-Me), and 9·30 (s, 13β-Me) (Found: M^+,

[27] A. Bowers and H. J. Ringold, *Tetrahedron*, 1958, **3**, 14.

388·2562. $C_{24}H_{36}O_4$ requires *M*, 388·2613), 6β-*fluoro*-5-*hydroxy*-3β-*methoxy*-5α-*pregnan*-20-*one* (13) (236 mg), m.p. 190—191° (from methanol), $[\alpha]_D$ +41° (*c* 0·8), $\nu_{max.}$ ($CHCl_3$) 3600, 3450 (OH), 2830, 1095 (OMe), and 1700 (C=O) cm^{-1}, τ ($CDCl_3$) 5·77 (d, J_{HF} *ca.* 50 Hz, 6-H), 6·3—6·7 (m, 3-H), 6·68 (s, OMe), 7·91 (s, 20-Me), 8·90 (d, J_{HF} *ca.* 5 Hz, 10β-Me), and 9·37 (s, 13β-Me) (Found: C, 72·05; H, 9·75. $C_{22}H_{35}FO_3$ requires C, 72·0; H, 9·65%), and 6α-*acetoxy*-3β-*methoxy*-1(10 → 5)abeo-5α-*pregn*-9-*en*-20-*one* (28) (98 mg), a gum, $[\alpha]_D$ +62·5° (*c* 0·92), ε_{215} 6520, $\nu_{max.}$ (CCl_4) 2825, 1095 (OMe), 1735 (acetate C=O), and 1708 [C(20)=O] cm^{-1}, τ 5·33 [q, *J* (apparent) *ca.* 11 and 4 Hz, 6-H], 6·28 (m, $W_{\frac{1}{2}}$ *ca.* 14 Hz, 3-H), 6·82 (s, OMe), 8·00 and 8·04 (s, OAc and 20-Me), 8·32 (s, 10-Me), and 9·31 (s, 13β-Me) (Found: M^+, 388·2608. $C_{24}H_{36}O_4$ requires *M*, 388·2613). The second less polar fraction was separated by t.l.c., in ether–light petroleum (b.p. 60—80°) (2 : 3), to give 6α,9-*epoxy*-3β-*methoxy*-1(10 → 5)abeo-5α-*pregnan*-20-*one* (29) (55 mg), a gum, $[\alpha]_D$ +59·6° (*c* 0·71), $\nu_{max.}$ (CCl_4) 2835, 1105 (OMe), and 1708 (C=O) cm^{-1}, τ (100 MHz; $CDCl_3$) 6·17 (d, *J ca.* 6 Hz, 6-H), 6·26 (m, $W_{\frac{1}{2}}$ *ca.* 18 Hz, 3-H), 6·75 (s, OMe), 7·91 (s, 20-Me), 9·15 (d, *J ca.* 7 Hz, 10β-Me), and 9·44 (s, 13β-Me) (irradiation at τ 8·5 caused the collapse of the 10-methyl doublet to a singlet) (Found: C, 75·8; H, 9·95. $C_{22}H_{34}O_3$ requires C, 76·25; H, 9·9%), and 3β-*methoxy*-5β-*pregnan*-6,20-*dione* (21) (399 mg), m.p. 172—173° (from methanol), $[\alpha]_D$ −2·5° (*c* 1·1), $\nu_{max.}$ (CCl_4) 2835, 1105 (OMe), and 1710 (C=O) cm^{-1}, τ 6·58 (m, $W_{\frac{1}{2}}$ *ca.* 8 Hz, 3-H), 6·79 (s, OMe), 7·98 (s, 20-Me), 9·19 (s, 10β-Me), and 9·42 (s, 13β-Me) (Found: C, 76·35; H, 9·8. $C_{22}H_{34}O_3$ requires C, 76·25; H, 9·9%).

Reaction of 5,6β-*Epoxy*-3β-*hydroxy*-5β-*pregnan*-20-*one* (8).—The epoxide (2·0 g) was treated with BF_3,Et_2O for 5 min. Acetylation of the crude product followed by preparative t.l.c., in benzene–ethyl acetate (10 : 1), gave 3β,6β-*diacetoxy*-5-*fluoro*-5α-*pregnan*-20-*one* (16) (1·25 g), m.p. 221—222° (from acetone), $[\alpha]_D$ 0° (*c* 0·77), $\nu_{max.}$ (CCl_4) 1740 (acetate C=O) and 1710 [C(20)=O] cm^{-1}, τ ($CDCl_3$) 4·6—5·4 (m, 3- and 6-H), 7·93, 7·96, and 8·03 (s, 3- and 6-OAc and 20-Me), 8·87 (s, 10β-Me), and 9·38 (s, 13β-Me) (Found: C, 68·85; H, 8·35. $C_{25}H_{37}FO_5$ requires C, 68·7; H, 8·55%), and 3β-acetoxy-5α-pregnane-6,20-dione (22) (518 mg), m.p. 155—156° (from aqueous methanol), $[\alpha]_D$ +26° (*c* 0·57) (lit.,[28] m.p. 155—156°). Some highly polar material (450 mg) was not further investigated.

Reaction of 3β-*Acetoxy*-5,6α-*epoxy*-5α-*cholestane* (9).—The epoxide (9) (516 mg) was treated with BF_3,Et_2O for 5 min. Preparative t.l.c. of the crude product, in benzene–ethyl acetate (10 : 1), gave 3β-acetoxy-6β-fluoro-5-hydroxy-5α-cholestane (14) (221 mg), m.p. 212—214° (lit.,[2a] 213—214°). Other fractions were not further investigated.

14-*Methyl*-1(10 → 5)abeo-18-*nor*-5α,8α,9β,14β-*cholest*-13(17)-*ene*-3,6-*dione* (41).—The epoxy-spiro-compound (37) [2a] [τ (220 MHz; $CDCl_3$) 6·17 (d, *J ca.* 5·2 Hz, 6-H), 6·24 (m, $W_{\frac{1}{2}}$ *ca.* 15 Hz, 3-H), 6·73 (s, OMe), 9·09 (d, *J ca.* 7·5 Hz, 10β-Me), 9·13 (d, side chain methyl groups), and 9·37 (s, 13β-Me)] (150 mg) in acetic acid (6 ml) and acetic anhydride (2 ml) at 0° was treated with BF_3,Et_2O (1·1 ml) and left for 12 h. Ether was added and the mixture was poured into 2N-sodium hydroxide. The ether extract was washed with water and dried. Evaporation of the solvent gave a crude product which was successively hydrolysed and oxidised in the usual manner. Preparative t.l.c. of the resultant product, in benzene, gave the *spiro-dione* (41) (20 mg), a gum, $\nu_{max.}$ (CCl_4) 1750 [C(3)=O] and 1715 [C(6)=O] cm^{-1}, τ 9·01 (low-field branch of 20-Me doublet), 9·08 (high-field branch of 20-Me doublet, 14β-Me), and 9·16 (d, side chain methyl groups) (irradiation at 83 Hz downfield from 20-Me doublet caused its collapse to a shoulder on the 14β-Me signal) (Found: M^+, 398·3187. $C_{27}H_{42}O_2$ requires *M*, 398·3185. Base peak *m/e* 285·1849. $C_{19}H_{25}O_2$ requires 285·1854).

3β,6α-*Diacetoxy*-14,19-*dimethyl*-1(10 → 5)abeo-18-*nor*-5α,8α,9β,14β-*cholest*-13(17)-*ene* (42).—The epoxy-spiro-compound (38) (62 mg) in ether (1·6 ml) and acetic anhydride (2·6 ml) at 0° was treated with BF_3,Et_2O (0·36 ml) and set aside for 2 h. Work-up as before gave the diacetate (42) (68 mg), a gum, $[\alpha]_D$ +37° (*c* 1·1), $\nu_{max.}$ (CCl_4) 1740 (C=O) cm^{-1}, τ 5·00 (m, $W_{\frac{1}{2}}$ *ca.* 15 Hz, 3-H), 5·34 (m, $W_{\frac{1}{2}}$ *ca.* 7 Hz, 6-H), 8·00 and 8·05 (s, 3- and 6-OAc), 8·98 and *ca.* 9·09 (20-Me), 9·12 and 9·21 (side chain methyl groups), and 9·18 (s, 14β-Me).

3β,6α-*Dihydroxy*-14,19-*dimethyl*-1(10 → 5)abeo-18-*nor*-5α,8α,9β,14β-*cholest*-13(17)-*ene* (43).—Hydrolysis of the diacetate (42) (60 mg), in the usual manner, gave the *diol* (43) (48 mg), a gum, $[\alpha]_D$ +41° (*c* 0·9), $\nu_{max.}$ (CCl_4) 3640 and *ca.* 3380 (OH) cm^{-1}, τ 5·78 (m, $W_{\frac{1}{2}}$ *ca.* 17 Hz, 3-H), 6·65 (m, $W_{\frac{1}{2}}$ *ca.* 6 Hz, 6-H), 8·98 and *ca.* 9·10 (20-Me), 9·10 and 9·20 (side chain methyl groups), 9·17 (s, 14β-Me) (Found: M^+, 416·3657. $C_{28}H_{48}O_2$ requires *M*, 416·3654).

14,19-*Dimethyl*-1(10 → 5)abeo-18-*nor*-5α,8α,9β,14β-*cholest*-13(17)-*ene*-3,6-*dione* (44).—Jones oxidation [26] of the diol (43) (62 mg), as before, gave the *dione* (44) (45 mg), a gum, $[\alpha]_D$ +91·5° (*c* 0·45), $\nu_{max.}$ (CCl_4) 1750 [C(3)=O] and 1715 [C(6)=O] cm^{-1}, τ 9·01 and 9·09 (20-Me), 9·09 and 9·20 (side chain methyl groups), and 9·12 (s, 14β-Me) (Found: M^+, 412·3335. $C_{28}H_{44}O_2$ requires *M*, 412·3341).

6α,9-*Epoxy*-3β-*hydroxy*-19-*methyl*-1(10 → 5)abeo-5α-*cholestane* (39).—The acetate (38) (40 mg) was hydrolysed in the usual manner to give the *alcohol* (39) (34 mg), m.p. 56—58 and 104° (from methanol), $[\alpha]_D$ +5·5° (*c* 0·75), $\nu_{max.}$ (CCl_4) 3600 and 3430 (OH) cm^{-1}, τ (100 MHz; $CDCl_3$) 5·71 (m, $W_{\frac{1}{2}}$ *ca.* 14 Hz, 3-H), 6·23 (d, *J ca.* 6 Hz, 6-H), and 9·37 (s, 13β-Me) (Found: C, 80·85; H, 11·6. $C_{28}H_{48}O_2$ requires C, 80·7; H, 11·6%).

6α,9-*Epoxy*-19-*methyl*-1(10 → 5)abeo-5α-*cholestan*-3-*one* (40).—The alcohol (39) (25 mg) was oxidised with Jones reagent [26] under the usual conditions to give the *ketone* (40) (20 mg), an amorphous solid, $[\alpha]_D$ 0° (*c* 0·42), $\nu_{max.}$ 1740 (C=O) cm^{-1}, τ 6·10 (d, *J ca.* 6 Hz, 6-H) and 9·38 (s, 13β-Me) (Found: M^+, 414·3501. $C_{28}H_{46}O_2$ requires *M*, 414·3498).

Reaction of the Epoxide (39) *with Boron Trifluoride–Ether in Acetic Anhydride–Acetic Acid.*—The epoxide (39) (200 mg) in acetic anhydride (1 ml) and acetic acid (7 ml) at 0° was treated with BF_3,Et_2O (1 ml) and set aside for 2 h. The mixture was worked up as before and preparative t.l.c. of the crude product, in benzene–ethyl acetate (40 : 1), gave the $\Delta^{13(17)}$-compound (42) (93 mg) and the $\Delta^{9(11)}$-compound (45) (112 mg), a gum (slightly impure), $\nu_{max.}$ (CCl_4) 1740 (C=O) cm^{-1}, τ 4·74 (m, $W_{\frac{1}{2}}$ *ca.* 6 Hz, 11-H), 4·85—5·25 (m, 3- and 6-H), 8·00 and 8·09 (s, 3- and 6-OAc), and 9·38 (s, 13β-Me).

3β,6α-*Dihydroxy*-19-*methyl*-1(10 → 5)abeo-5α-*cholest*-9(11)-*ene* (46).—The diacetate (45) (50 mg) was hydrolysed and, after preparative t.l.c., gave the *dihydroxy*-$\Delta^{9(11)}$-*compound* (46) (38 mg), m.p. 164—165° (from methanol), $[\alpha]_D$ +29° (*c* 0·9), $\nu_{max.}$ (CCl_4) 3640 and 3380 (OH) cm^{-1}, τ 4·79 (m, $W_{\frac{1}{2}}$ *ca.* 7 Hz, 11-H), 6·1—6·7 (m, 3- and 6-H), and 9·38 (s, 13β-Me) (Found: C, 80·9; H, 12·05. $C_{28}H_{48}O_2$ requires C, 80·7; H, 11·6%).

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19-*Methyl*-1(10 ⟶ 5)-abeo-5α-*cholest*-9(11)-*ene*-3,6-*dione* (47).—The dihydroxy-$\Delta^{9(11)}$-compound (46) (25 mg) was oxidised to the *diketone* (47) (23 mg), m.p. 109—111° (from methanol), $[\alpha]_D$ +35° (*c* 0·46), $\nu_{max.}$ (CCl_4) 1755 [C(3)=O] and 1715 [C(6)=O] cm^{-1}, τ (100 MHz; $CDCl_3$) 4·44 (m, $W_{\frac{1}{2}}$ *ca.* 8 Hz, 11-H), and 9·30 (s, 13β-Me) (Found: M^+, 412·3345. $C_{28}H_{44}O_2$ requires *M*, 412·3341).

3β,6α-*Diacetoxy*-19-*methyl*-1(10 ⟶ 5)abeo-5α-*cholest*-9(11)-*en*-12-*one* (48).—*N*-Bromosuccinimide (110 mg) and calcium carbonate (40 mg) were added to a solution of the diacetate (45) (87 mg) in dioxan (3 ml) and water (0·6 ml). The mixture was stirred and irradiated with a tungsten lamp for 1 h at room temperature, after which it was poured into water and extracted with ether (×2). The combined extracts were washed with sodium hydrogen carbonate solution and dried. Removal of the solvent gave a crude product which, after preparative t.l.c. in benzene–ethyl acetate (19 : 1), gave the conjugated *enone* (48) (30 mg), a gum, $[\alpha]_D$ +63·5° (*c* 0·5), $\lambda_{max.}$ (EtOH) 237 nm (ε 11,100), $\nu_{max.}$ (CCl_4) 1740 (acetate C=O) and 16·85 [C(12)=O] cm^{-1}, τ (100 MHz; $CDCl_3$) 4·35 (d, *J* *ca.* 2 Hz, 11-H), 4·80—5·12 (m, 3- and 6-H), 8·92 and 8·99 (s, 3- and 6-OAc), and 9·18 (s, 13β-Me) (Found: M^+, 514·3623. $C_{32}H_{50}O_5$ requires *M*, 514·3658).

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