The Rearrangement of 3β-Acetoxy-9,11-epoxylanostanes by Boron Trifluoride–Diethyl Ether

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The rearrangement of 3β-acetoxy-9β,11β-epoxylanostan-7-one (1b) by boron trifluoride–diethyl ether leads to the ring B-enlarged products 3β-acetoxy-9a-homo-19-norlanosta-1(10),9(11)-dien-7-one (4) and the isomeric 9a(10),9(11)-diene, as well as to the previously described cucurbitane (2a) and the new cucurbitanes 3β-acetoxy-11β-hydroxy-19(10→9β)*abeo*-lanost-1(10)-en-7-one (5a) and its acetate (5b). Rearrangement of 3β-acetoxy-9α,11α-epoxylanostan-7-one (1a) by boron trifluoride–diethyl ether effects migration of the angular methyl group at C-13 to give 3β-acetoxy-18(13→12β)*abeo*-lanosta-8,13(17)-dien-7-one (6). The ^{13}C n.m.r. spectra of these skeletally modified lanosterol derivatives are discussed, including the cucurbitanes having 10α and 10β stereochemistry.

A KEY step in the conversion of the commercially available lanosterol into the biologically active triterpenes of the cucurbitane series is the migration of the angular methyl group C-19 from C-10 to C-9. Several reports [1] have described such attempts; the most successful, described recently by Paryzek,[2] involved the rearrangement of the β-epoxide (1b) using boron trifluoride–diethyl ether in acetic anhydride to give the cucurbitane derivative (2a) in 58% yield together with 3β-acetoxylanostane-7,11-dione (3a). With benzene as solvent, the sole product was reported [2] to be the diketone (3a). We have previously investigated this rearrangement of the β-epoxide (1b) as a potential route to the cucurbitane skeleton. The C-7 ketone was incorporated to suppress carbonium character at C-8 thereby discouraging the rearrangement to the 8α,9β,14β-dammarane skeleton [3] but still allowing the migration of C-19.

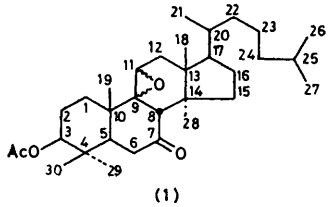
The rearrangement of the β-epoxide (1b) by boron trifluoride–diethyl ether in benzene was temperature dependent. Thus, when the rearrangement was carried out at room temperature, the only major product was the diketone (3a) (*cf.* ref. 2); when the rearrangement was effected at 10 °C, two major products were obtained, the diketone (3a) (34%) and a new compound (33%) to which is assigned the ring B-enlarged structure, 3β-acetoxy-9a-homo-19-norlanosta-1(10),9(11)-dien-7-one (4). Under the latter conditions two minor products were also obtained, namely the cucurbitane, 3β-acetoxy-11β-hydroxy-19(10→9β)*abeo*-lanost-1(10)-en-7-one (5a) (4%) and 3β-acetoxy-9a-homo-19-norlanosta-9a(10),9(11)-dien-7-one (1%). The rearrangement of the β-epoxide (1b) by boron trifluoride–diethyl ether in acetic anhydride at 0 °C gave, in addition to the reported [2] products (2a) (47%) and (3a) (14%), the cucurbitane 3β,11β-diacetoxy-19(10→9β)*abeo*-lanost-1(10)-en-7-one (5b) (24%) with the non-conjugated double bond. Rearrangement of the β-epoxide (1b) by boron trifluoride–diethyl ether in nitromethane at room temperature gave the diketone (3a) (80%) as the sole isolable product.

The rearrangement of the α-epoxide (1a) using boron trifluoride–diethyl ether in benzene or nitromethane led to 3β-acetoxy-9β-lanostane-7,11-dione (3b) (50 and 75% yield respectively). With acetic anhydride as solvent at 0 °C the only isolable product (70%) was 3β-acetoxy-18(13→12β)*abeo*-lanosta-8,13(17)-dien-7-one (6).

The structure for the ring B-enlarged product (4) was deduced from the following evidence. It had the constitution $C_{32}H_{50}O_3$ (elemental and mass spectral analysis) and possessed u.v. absorption characteristic of an isolated carbonyl group ($\lambda_{max.}$ 296 nm, ε 38) with strong end-absorption typical of isolated olefinic unsaturation and i.r. absorption at 1 698 and 1 745 cm^{-1} associated with the isolated ketone and acetate functions. The molecular formula was consistent with a tetracyclic structure incorporating two non-conjugated carbon–carbon double bonds. The ^1H n.m.r. spectrum (100 MHz) revealed the presence of a multiplet (2H) centred at δ 5.4 associated with two vinylic protons, unresolved by the use of europium shift reagent. At 270 MHz these two protons were separated as doublets of doublets centred at δ 5.39 (*J* 2.5 and 5.5 Hz) and δ 5.45 (*J* 4 and 7 Hz) indicating that each vinylic proton was vicinal to a methylene group. The signal for 3α-H was at δ 4.75 (dd, *J* 6 and 10 Hz), at *ca.* 0.3 p.p.m. lower field than in lanosterol derivatives and suggestive of conformational or structural change associated with ring A. Furthermore, proton resonances for only seven methyl groups (including only four singlets, at δ 0.72, 0.80, 0.83, and 0.90) were discernible. The natural abundance ^{13}C n.m.r. spectra of (4) (see below and Table) revealed the non-functionalised carbons of rings A and B as comprising only one quaternary carbon, two methines, three methylenes, and only two methyl groups (excluding the acetoxy-methyl group). The absence of one methyl group and one quaternary carbon indicated rearrangement at the C-10 bridgehead. The methines C-5 and C-8 were distinguished through the lack of virtual coupling in the latter. Methylene carbons C-2, C-6, and C-9a (C-19) were distinguished as follows: C-2 by its location at high field and C-9a by its appearance as a clean triplet at 42.0 p.p.m. [showing large residual coupling and lack of virtual coupling (compared to the signal for C-6) during off-resonance decoupling at δ −2] consistent with its attachment to protons at low-field (in the region δ 2.5—3.3, doubly allylic protons) and the absence of vicinal protons.

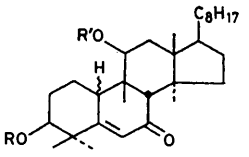
In agreement with the structure (4), isomerisation was

effected by acid or base leading to the conjugated ketone (7a) with $\lambda_{max.}$ 252 nm (ε 8 000), $\nu_{max.}$ 1 735 (acetate) and 1 665 cm^{-1} (conjugated ketone), δ 4.78 (dd, *J* 6 and 10 Hz)



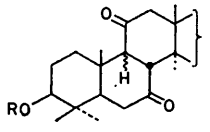
(1)

a: α - epoxide
b: β - epoxide



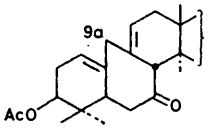
(2)

a; R = R' = Ac, 10α
b; R = H, R' = Ac, 10α
c; R = R' = H, 10α
d; R = Ac, R' = H, 10α
e; R = R' = H, 10β
f; R = Ac, R' = H, 10β
g; R = R' = Ac, 10β
h; R = H, R' = Ac 10β

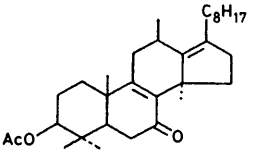


(3)

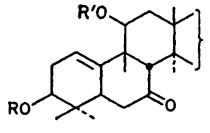
a; R = Ac, 9α
b; R = Ac, 9β
c; R = H, 9α



(4)

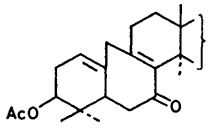


(6)

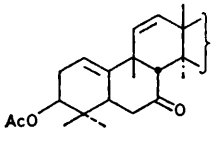


(5)

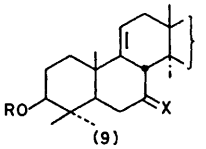
a; R = Ac, R' = H
b; R = R' = Ac
c; R = H, R' = Ac
d; R = R' = H



(7a)
(7b) 5,6 - didehydro



(8)



(9)

a; R = H, X = H_2
b; R = H, X = H_2, 9,11 - dihydro
c; R = Ac, X = O

and 5.44 (one vinylic proton). The ^{13}C n.m.r. spectrum showed resonances (Table) consistent with this double-bond migration. Notably, resonances for carbons in ring A were little perturbed, those for the rings C, D region showed variation in shift similar to those found between the C-9(11) and C-8 unsaturated lanostane series,[4] and the resonance for the methine C-8 in (4) was replaced by a methylene resonance at 29.9 p.p.m. consistent with C-12 in (7a). Clearly, the new unsaturation was located at C-8, that at C-1(10) being unaffected by the conditions of isomerisation. The resonances for C-6 and C-9a were distinguished as for (4). The oxidation of (7a) by selenium dioxide in acetic acid afforded the trienone (7b) with constitution $C_{32}H_{48}O_3$, $\lambda_{max.}$ 297 nm (ε 14 000), $\nu_{max.}$ 1 730 (acetate), 1 650 and 1 615 cm^{-1} (conjugated ketone), δ 5.93 (d, *J* 2 Hz) and 5.73 (m) (6-H and 1-H), 4.76 (m, 3α-H). Irradiation at δ 5.73 led to a singlet at δ 5.93. The off-resonance decoupled ^{13}C n.m.r. spectrum revealed C-9a as a clean triplet centred at 41.7 p.p.m. C-1 and C-6 were distinguished through C-1 appearing as a line-broadened doublet (*cf.* the sharp appearance of the C-6 doublet) in the off-resonance decoupled spectrum. The most significant contribution of the C-5 unsaturation was at the C-4 *gem*-dimethyl group where comparative lack of shift distinction between the methyls implies a similar homoallylic relationship [4] to the C-5 unsaturation.

The rearranged compounds of this B-homo-series were characterised further as the alcohol obtained through the reduction of the non-conjugated ketone (4) by sodium borohydride, the derived acetate, and the conversion of the conjugated ketone (7a) into the enol acetate, 3β,7-diacetoxy-9a-homo-19-norlanosta-1(10),7,9(11)-triene.

The minor product (1% yield) from the rearrangement of (1b) in benzene was formulated as 3β-acetoxy-9a-homo-19-norlanosta-9a(10),9(11)-dien-7-one on the basis of its constitution $C_{32}H_{50}O_3$, together with the following spectral evidence: $\lambda_{max.}$ 238 nm (ε 19 200), $\nu_{max.}$ 1 735, 1 265 (acetate), and 1 705 cm^{-1} (ketone); δ 6.20 ($W_{\frac{1}{2}}$ 4 Hz, 9a-H), 5.71 (m, 11-H), and 4.50 (dd, *J* 5 and 12 Hz). The other minor product was identified as (5a) through i.r. absorption at 3 470 (OH), 1 750, 1 260 (acetate), and 1 695 cm^{-1} (ketone), δ 5.67 (1-H), 4.80 (3α-H), 4.39 (11α-H), 2.62 (8-H), and 2.04 (acetate) and the dehydration by phosphoryl chloride in pyridine to give the diene (8). The ^1H n.m.r. (C_6D_6) spectrum of (8) showed olefinic resonance at δ 5.46 (m, 1-H), 6.01 (d, *J* 10 Hz), and 5.61 (d, *J* 10 Hz). The lack of additional coupling in these two doublets was consistent only with the olefinic linkage being flanked by saturated quaternary carbons in a six-(or seven-)membered ring. In this case, this feature is possible only at C-11(12) in a skeleton in which C-9 is a quaternary carbon. The structure (5a) was also supported by the ^{13}C n.m.r. spectrum, together with those of related compounds (see below).

The product (24%) from the rearrangement of the epoxide (1b) in acetic anhydride was shown to have the structure (5b) by its identity with the product of acetylation of (5a).

The proof of structure of the rearrangement product (3b) derived from the epoxide (1a) (using boron trifluoride–diethyl ether in benzene) followed from the constitution $C_{32}H_{52}O_4$, i.r. absorption at 1 730, 1 265 (acetate), and 1 705 cm^{-1} (ketone) and n.m.r. spectrum [δ 4.78 (m, 3α-H), 2.01 (OAc), 1.17 (s, Me), 0.89 (s, 2 × Me), 0.87 (d, Me), 0.86 (d, 2 × Me), 0.82 (s, Me), and 0.73 (s, Me)]. Most importantly, this product was isomerised readily by base to give, after reacetylation, the known diketone (3a) showing that it was epimeric at the enolis-

^{13}C N.mr. data *

C	(1a)	(1b)	(2a)	(2b)	(2c)	(2d)	(2e)	(2f)	(2g)	(2h)	(3a)	(3b)	(3c)	(4) †	(5a)	(5b)	(5c)	(5d)	(6)	(7a) †	(7b) †	(8)	(9c)
1	28.4	30.6	22.3	21.7	21.9	22.5	25.5	25.0	24.8	25.3	35.5	31.4	35.8	116.5	117.3	118.5	119.1	117.8	35.1	118.5	127.0	119.0	35.2
2	23.0	23.0	25.9	28.6	28.6	27.1	30.2	26.8	26.7	30.1	23.3	23.5	27.0	27.7	29.4	29.6	32.8	32.7	23.8	28.4	25.5	29.1	23.8
3	79.0	79.9	77.4	76.2	76.4	78.1	75.7	77.3	77.0	75.6	79.6	79.5	77.9	76.1	75.8	75.9	74.0	73.9	79.4	76.0	76.3	75.9	80.0
4	37.6	37.2	41.0	42.6	42.6	41.1	43.4	41.8	41.8	43.3	37.9	37.7	39.1	35.9	35.5	36.0	37.3	36.9	37.6	36.0	38.9	35.8	37.8*m*
5	45.8	44.2	165.8	167.7	167.5	166.4	168.6	166.5	166.4	168.3	52.1	39.8	52.3	41.0	42.0	42.8	42.9	42.4	49.5	43.9	153.8	43.9	47.5
6	39.2	38.0	124.7	125.4	125.8	125.2	124.2	124.6	124.6	124.1	38.7	35.6	39.1	44.3	38.7 *g*	37.3	37.3	38.5 *h*	35.5	43.2	127.5	38.5	38.7
7	207.9	213.0	201.2	201.7	202.5	202.7	203.7	203.0	201.9	202.5	208.4	212.3 *e*	209.2	213.4	214.6	213.5	214.5	215.6	199.5	204.6	197.1	213.9	211.8
8	52.7	54.9	58.2	58.3	58.2	58.2	58.0	57.9	58.0	58.0	52.7	53.9 *f*	52.7	61.9	59.0	58.6	58.3	58.6	138.8	140.8	142.9	58.8	56.2
9	68.5	66.9	40.4	40.3	41.4	41.4	41.1	41.2	40.3	40.1	60.0	52.5 *f*	60.3	131.2	43.1	41.9	41.7	42.9	171.5	145.6	138.1	40.4	143.2
10	37.6	38.0	40.7	41.0	41.4	41.1	41.3	41.1	40.8	40.9	36.4	35.8	36.6	138.5	141.1	139.2	139.2	140.9	39.4	134.7	130.8	142.5	38.2*m*
11	53.8	60.5	72.2	72.6	71.6	71.4	71.4	71.3	72.3	72.5	209.0	214.2 *e*	209.5	124.2	71.3	73.9	74.0	71.5	25.4	29.9	29.4	132.0 *l*	117.5
12	34.1 *a*	32.9	35.7	35.7	38.4	38.4	38.4	38.4	35.7	35.6	52.1	54.6	52.3	37.0	39.0 *g*	36.0	35.6	38.7 *h*	40.5	31.2 *i*	30.3 *j*	133.7 *l*	37.0
13	44.9	43.4	44.2	44.3	44.6	44.6	44.6	44.6	44.3	44.3	48.7	48.4	48.7	44.5	44.6	44.3	44.2	44.6	128.3	44.7	44.9	48.0	44.4
14	45.3	48.2	48.1	48.2	48.4	48.4	48.3	48.4	48.2	48.1	46.2	46.6	46.2	48.4	49.2	49.3	49.2	49.3	50.7	49.3	48.9	49.6	47.0
15	35.1 *a*	35.3	34.0	34.1	34.2	34.2	34.1	34.1	34.0	34.1	32.8	38.7	32.8	33.3	34.3	34.1	34.0	34.2	32.6	31.5 *i*	30.7 *j*	36.7	34.2
16	28.1	27.4	27.1	27.3	27.4	27.4	27.3	27.3	27.2	27.2	28.3	28.0	28.3	27.5	27.4	27.4	27.2	27.3	28.8	28.5	28.7	33.1	27.8
17	49.5	51.3	49.9	50.1	50.2	50.2	50.1	50.1	50.1	49.9	48.3	54.4	48.4	49.9	50.8	50.2	50.0	50.6	131.8	48.6	49.7	45.9	49.7
18	15.5	17.2 *b*	16.7	16.7	17.3	17.3	17.2	17.2	16.6	16.6	15.8	18.5	15.9	14.8	18.4	17.6	17.4	18.5	20.6	15.5	15.0	20.2	15.0
19	18.6	16.3 *c*	21.4	21.5	21.6	21.6	21.8	21.9	21.9	21.5	13.4	21.9	13.4	42.0	24.3	23.6	23.4	24.1	19.5	41.1	41.7	23.3	20.2
20	35.6	35.8	35.7	35.7	35.9	35.8	35.8	35.8	35.7	35.6	35.5	35.6	35.5	36.1	36.0	36.0	35.8	36.0	32.3	36.2	36.3	36.1	35.9
21	18.3	18.3	18.6	18.5	18.6	18.6	18.5	18.5	18.5	18.5	18.1	18.0	18.2	18.4	18.7	18.6	18.5	18.5	17.6	18.6	18.5	18.4	18.2
22	36.1	36.0	36.0	36.1	36.2	36.2	36.2	36.2	36.1	36.0	36.0	35.6	36.0	35.9	36.0	36.0	36.0	36.1	34.9	36.2	36.3	36.1	36.3
23	23.8	23.9	23.7	23.7	23.8	23.8	23.7	23.7	23.6	23.6	23.6	23.9	23.6	23.8	23.8	24.0	23.7	23.8	22.5	23.8	23.9	23.9	23.8
24	39.2	39.2	39.1	39.2	39.3	39.2	39.2	39.2	39.2	39.1	39.1	39.1	39.1	39.2	39.2	39.3	39.1	39.2	39.0	39.2	39.3	39.2	39.3
25	27.7	27.8	27.7	27.7	27.8	27.7	27.7	27.7	27.7	27.6	27.6	27.7	27.7	27.8	27.7	27.8	27.6	27.7	27.8	27.7	27.8	27.8	27.8
26	22.6	22.7	22.5	22.5	22.6	22.5	22.5	22.5	22.5	22.4	22.5	22.6	22.5	22.5	22.5	22.7	22.5	22.5	22.5	22.5	22.6	22.5	22.6
27	22.3	22.4	22.3	22.2	22.3	22.3	22.2	22.2	22.2	22.2	22.2	22.3	22.2	22.2	22.2	22.4	22.2	22.2	22.5	22.2	22.3	22.3	22.4
28	18.3	19.0 *b*	17.7	17.7	17.9	17.9	18.0	17.9	17.8	17.8	17.3	18.5	17.3	18.1	20.8	20.3	19.9	20.5	26.8	25.4	25.8 *k*	20.2	17.6
29	26.7	27.1	27.1	27.3	27.4	26.0	20.6 *d*	21.9	21.5	20.6	27.4	26.7	27.5	23.9	28.4	30.4	13.4	29.1	27.6	23.9	28.1 *k*	28.0	27.1
30	16.2	16.1 *c*	24.1	24.6	24.6	24.3	23.9 *d*	23.9	23.8	23.6	15.7	15.3	14.6	14.8	15.5	13.6	12.1	14.0	16.4	14.2	24.2 *k*	13.4	15.5

* The δ values are in p.p.m. downfield relative to Me_4Si: $\delta(Me_4Si) = \delta(CDCl_3) + 76.9$ p.p.m. Where applicable the acetyl $\delta(Me) = 20.9 \pm 0.1$ p.p.m. and $\delta(CO) = 170.6 \pm 0.2$ p.p.m. † For convenience, the assignment for C-9a is given under C-19 in these rearrangement products.

a–m Assignments bearing the same superscript may be interchanged.

able position C-9. This 9α-isomer (3a) showed a low-field methyl resonance at δ 1.30 and 3α-H at δ 4.50 compared to the corresponding values δ 0.89 and 4.78 in the 9β-diketone (3b). These shifts are considered to be due to a flexible conformation for ring C in which C-28 lies in the shielding cone of the 11-ketone and 3α-H lies in the deshielding zone.

The product from the rearrangement of the α-epoxide (1a) by boron trifluoride–diethyl ether in acetic anhydride was shown to have structure (6) on the basis of the following evidence. The molecular constitution $C_{32}H_{50}O_3$ was consistent with two double bonds in a tetracyclic skeleton and the ^{1}H n.m.r. spectrum revealed no olefinic proton and no vinylic methyl group. The u.v. ($\lambda_{max.}$ 249 nm, ε 12 000) and i.r. ($\nu_{max.}$ 1 660 cm^{-1}) spectra indicated that one tetra-substituted double bond was in conjugation with the C-7 ketone. The n.m.r. shift for 3α-H was at the usual position, δ 4.52 (dd, *J* 5 and 9 Hz). Principal spectral differences for this product (compared with the lanostane and cucurbitane derivatives) must be associated with a different environment for the iso-octyl side-chain. Thus, the mass spectrum gave the base peak (*m/e* 369) due to loss of the side-chain [characteristic of compounds containing a 13(17)-double bond [5]] and the ^{13}C n.m.r. spectrum revealed differences in carbon shifts for the side-chain especially at those sites close to the point of attachment to ring D. This evidence was consistent only with the additional unsaturation being in the ring D region. The ^{13}C n.m.r. spectrum showed the presence of eight methyl groups (also seen in the ^{1}H n.m.r. spectrum), the resonance expected for an unperturbed ring A, the loss of a low-field quaternary carbon associated with the C/D ring junction and novel values for the carbon shifts for the two methines C-12 and C-20 at 40.5 and 32.3 p.p.m. This evidence was consistent only with a tetra-substituted double bond at C-13(17) and migration of the angular methyl group from C-13 to C-12. Interestingly, the conjugated ketone (6) formed the enol acetate through enolisation towards C-6, showing u.v. absorption at 262 nm (ε 4 000) associated with the homo-annular diene chromophore.

The interpretation of the ^{13}C n.m.r. spectra of the compounds related to the cucurbitane skeleton involved the selective manipulation of functionality (*cf.* ref. 6) to cause predictable variations in carbon shift. Thus, in the series (5a—d), selective hydrolysis of (5b) led to the monoacetate (5c), more vigorous conditions being required to hydrolyse the 11β-acetate. The greater steric hindrance at C-11 allowed also the selective acetylation of the diol (5d) to the monoacetate (5a).

A similar selective hydrolysis of the diacetate (2a) led to the monoacetate (2b) retaining the 11-acetoxy function. The conditions required [2] to complete the hydrolysis led to the diol (2c) (40%), together with the more soluble diol (2e) isomeric at C-10. Selective acetylation of (2c) gave the C-3 acetate (2d) which, on further acetylation regenerated the original diacetate (2a). The principal hydrolysis product (2e) (60% yield) (*cf.* ref. 2) formed, first, the monoacetate (2f) leading to the diacetate (2g) which was hydrolysed to the isomeric monoacetate (2h). The comparison of the ^{13}C n.m.r. spectra of the cucurbitanes (2a—h), being four pairs isomeric at C-10, revealed major differences associated only with C-1 (*ca.* 3 p.p.m.) and the methyl groups at C-4 (*ca.* 4 p.p.m.). These variations must be associated with conformational change in ring A. Dreiding models revealed that the preferred conformation of ring A is such that the 3β-substituent is equatorial in the 10β-series and quasi-axial in the 10α-series. This change in orientation may be the cause of the isomerisation at C-10.

The assignments of ^{13}C n.m.r. shifts to the compounds described above which possess the lanostane skeleton are based upon those given for lanost-9(11)-en-3β-ol (9a) [4] and lanostan-3β-ol (9b); [7] the assignments given [7] for the latter should be interchanged at C-4, C-10 and at C-28, C-30 on the basis of shift variations (−1 and +1 p.p.m. respectively) associated with esterification at C-3β (*cf.* ref. 6). The assignment of resonances to 3β-acetoxylanost-9(11)-en-7-one (9c) was straightforward, methines

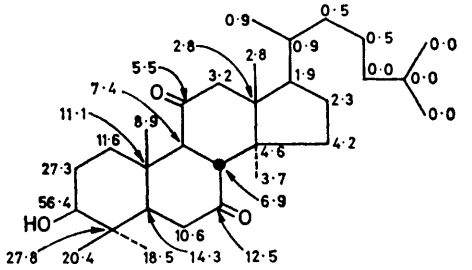


FIGURE 1

in the nucleus being distinguished through C-8 showing lack of virtual coupling and C-17, being remote in ring D, showing least perturbation (*cf.* C-5) upon introduction of the 7-oxo-function. The upfield shift (*ca.* 5 p.p.m.) at C-5 due to the 7-ketone contrasts markedly with that in the steroid series [8] (+2 p.p.m.) and can be associated with conformational change in ring B. Carbon shifts distinguished between the epoxides (1a) and (1b) isomeric at C-9, C-11. The principal effect from epoxidation of the olefin was the shielding at C-1, C-5, C-8, and C-12. The resonances for C-1 and C-12 were allocated on the basis of the spectra of the corresponding 2-oxo-compound [9] in which that for C-12 was unchanged and that for C-1 was deshielded by 16 p.p.m. The differences in chemical shifts between these two epoxides at C-9 (1.6 p.p.m.), and more especially at C-11 (6.7 p.p.m.), may be generally applicable to stereochemical distinction between such epoxides. Shift assignments for the diketone (3a) were based upon those for the corresponding alcohol (3c) derived from a lanthanide-induced shift study (Figure 1). Interestingly, a smooth variation in shift was seen throughout the molecule, dominated by pseudo contact of the shift reagent at the hydroxy-function. The ^{13}C n.m.r. spectrum for the 9β-diketone (3b) revealed carbon-shift variation throughout the nucleus due to the isomerisation at C-9 and resultant

gross conformational change in ring C. These assignments were assisted by a lanthanide-shift reagent study upon the 7-deoxy-analogue (Figure 2).

The assignment of ^{13}C n.m.r. resonances to the B-homolanostanes (4), (7a), and (7b) was based on a comparison with those for (9c) which allowed the allocation of shifts to all carbons to the right of a line between C-8 and C-11. Comparison with the spectrum of (9c) also enabled allocation of resonances for the quaternary carbon C-4 together with the attached methyl groups and C-2 which showed the expected downfield shift. Resonances for the remaining non-functionalised carbons, the methines C-5 and C-8 and the methylenes C-6 and C-9a, were distinguished in the off-resonance decoupled spectra (see above). The downfield shifts [*cf.* (9c)] of C-2 (3.9 p.p.m.), C-6 (5.6 p.p.m.), and C-8 (5.7 p.p.m.) were consistent with the removal of the γ-effect due to C-19. The loss of C-19 also accounts for the upfield shift (removal of β-substituent) [10] seen at C-5. Allocation of resonances to the olefinic methines was based on the expected downfield shift for C-11 [*cf.* (9c)] due to replacement of the γ-substituent (C-1) by the β-H (9a-H) and the near constancy of the resonance for C-1 in the conjugated ketone (7a). The resonances associated with ring A were similar to those found for the cucurbitanes (5a—d) possessing the C-1(10) unsaturation.

The ^{13}C n.m.r. spectra of the cucurbitane terpenoids were assigned in three classifications, those possessing C-1(10) unsaturation and 5α,9β-stereochemistry, (5a—d), those with C-5(6) unsaturation with 10α stereochemistry, (2a—d), and those isomeric at C-10, (2e—h). The assignment of resonances to (5a—d) was facilitated by the invariance of the resonances from the side-chain and ring D and by shifts expected [6] due to acetylation at C-3 and/or C-11. Thus, acetylation at C-3 distinguished quaternary carbons C-4 and C-9 and methyls C-19 and C-29. Acetylation of the 11-hydroxy-group caused predictable changes in the immediate environment but, in addition, caused long-range effects (*e.g.* at C-6, C-29, and C-30) indicative of conformational mobility in this ring system. A further example of this was seen in the dehydration product (8) where carbon shift values in ring D were also affected greatly.

The location of unsaturation at C-5, rather than at

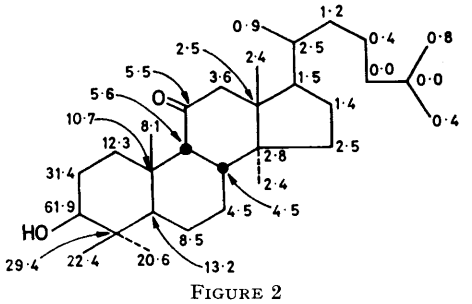


FIGURE 2

C-1(10) in the products from rearrangement (2a—d) resulted in little deviation of shift for carbons to the right of the C-8, C-9 axis. Major deviations within the rings A, B region (*e.g.* at C-2, C-3, C-4, C-9) were in accord with the parameters derived [4] for allylic and homoallylic effects of unsaturation. The most significant variation from the resonances for the C-1(10)

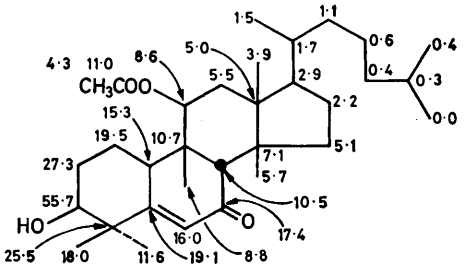


FIGURE 3

unsaturated series was found at the C-4 geminal dimethyl group where, as in the case of the B-homo-compound (7b), the two methyl groups revealed a lessening of chemical-shift difference. They were distinguished through a lanthanide-shift study upon the monoacetate (2b) (Figure 3) in which the relative shift perturbations were consistent with a time-averaged location of the metal on an extension of the 3-O, C-9 axis and *ca.* 340 pm from the hydroxy-oxygen. A comparison between Figures 1—3 and the lanthanide-shift studies on lupeol [6] indicated that the C-7 ketone function gave rise to a small but clearly discernible modification of the perturbation pattern and that this effect was enhanced in the conjugated ketone. The corresponding effect due to the C-11 ketone was barely discernible.

The ^{13}C n.m.r. shifts for the cucurbitanes having 10β stereochemistry (2e—h) showed significant differences only in ring A. Surprisingly, the resonance for C-8 did not show the downfield shift expected from the additional β-(10-H)-interaction. The variation of C-1 (*ca.* +3 p.p.m.) due to this isomerism was interpretable in terms of conformational change in ring A resulting in a β-hydrogen interaction between C-1 and C-3 in the 10β-series possessing equatorial 3β-oxygenation. The upfield shift of the resonance due to C-2 (−3.5 p.p.m.) associated with acetylation at C-3 was in accord with that observed [6] in other triterpene series.

EXPERIMENTAL

Melting points were determined on a Reichert hot-stage apparatus and are uncorrected. Optical rotations are for *ca.* 0.5% solutions in chloroform at 20 °C in a 0.2 dm cell using a Bendix automatic polarimeter. Mass spectra were determined on an AEI MS9 double-focusing mass spectrometer at 70 eV. I.r. spectra were measured, unless otherwise stated, using chloroform solutions; only the more characteristic frequencies are quoted. U.v. spectra are for solutions in ethanol. Silica gel used for chromatography was Merck silica gel H (type 60); short, wide columns were used, typically 2 g of silica gel in a column 0.5 cm in diameter, 10 g in a column of 2.5 cm diameter, 50 g in a column of 4.5 cm diameter. Light petroleum used had b.p. 60—80 °C. Proton n.m.r. spectra were obtained with a Varian HA100 instrument with deuteriochloroform as solvent

except where otherwise stated. Microanalyses were carried out by the Australian Microanalytical Service, Melbourne, and by Mr. J. Sussman of the University of New South Wales.

The ^{13}C n.m.r. spectra were recorded on a Brüker WP-60 n.m.r. spectrometer operating at 15.08 MHz in the Fourier transform mode. Spectra were determined with a digital resolution of ±1 Hz (spectral width of 3 759 Hz with 4 K data points in the real spectrum), pulse flip angle of *ca.* 50° and 2 000—5 000 transients for proton-decoupled spectra depending upon the triterpene concentration (*ca.* 0.5M). The off-resonance decoupling experiments were carried out with ^1H decoupler offset 2 p.p.m. upfield or 5 p.p.m. downfield from $SiMe_4$ and ^1H irradiating power adjusted to 0.8—1.2 W. The lanthanide-shift studies used $Yb(DPM)_3$ with molar ratio of reagent of up to 0.3 and led to gradients $\Delta\delta/Yb(DPM)_3$ molar ratio, normalised to unit molar ratio of shift reagent and obtained by the least-squares fitting method.

Epoxidation of 3β-*Acetoxylanost*-9(11)-*en*-7-*one*.—*m*-Chloroperbenzoic acid (85%, 300 mg) was added to a solution of 3β-acetoxylanost-9(11)-en-7-one [11] (200 mg) in acid-free chloroform (4 ml) and the mixture set aside for 12 h at 25 °C. The mixture was diluted with chloroform, washed with saturated sodium hydrogen carbonate solution and water, dried, and evaporated. The crude product was recrystallised from methanol (containing a trace of pyridine) and then dichloromethane–methanol to give the β-epoxide (1b) as needles (120 mg), m.p. 218—219 °C (lit.,[2] 216—218 °C), $[\alpha]_D$ +57°, $\nu_{max.}$ 1 735, 1 265 (OAc), and 1 706 cm^{-1} (ketone); δ 4.53 (1 H, dd, *J* 6 and 9 Hz, 3-H), 3.58 (1 H, s, $W_{\frac{1}{2}}$ 5 Hz, 11-H), 2.81 (1 H, s, 8-H), and 2.03 (3 H, s. OAc); *m/e* 500 (M^+, 40%) (Found: C, 76.9; H, 10.5. Calc. for $C_{32}H_{52}O_4$: C, 76.8; H, 10.5%). The mother liquors from the above recrystallisations were combined and evaporated; the product crystallised from chloroform–methanol to give the α-epoxide (1a) as plates (50 mg), m.p. 173—174 °C (lit.,[2] 173—175 °C), $[\alpha]_D$ +12°, $\nu_{max.}$ 1 735, 1 268 (OAc), and 1 720 cm^{-1} (ketone); δ 4.48 (1 H, m, 3-H), 3.15 (1 H, d, *J* 5 Hz, 11-H), 2.83 (1 H, s, 8-H), and 2.02 (3 H, s, OAc); *m/e* 500 (M^+, 2%) (Found: C, 76.9; H, 10.2. Calc. for $C_{32}H_{52}O_4$: C, 76.8; H, 10.5%).

Rearrangement of 3β-*Acetoxy*-9β,11β-*epoxylanostan*-7-*one* (1b) *by Boron Trifluoride–Diethyl Ether in Benzene*.—Boron trifluoride–diethyl ether (2 ml) was added to a solution of the β-epoxide (1b) (350 mg) in dry benzene (7 ml) and the solution set aside for 6 h at 10 °C. The mixture was diluted with ether, washed with sodium hydrogen carbonate solution and water, dried, and evaporated *in vacuo* to give a crude product which was adsorbed from light petroleum onto a column of silica gel (6 g). Elution with ether–light petroleum (1 : 100) gave 3β-*acetoxy*-9a-*homo*-19-*norlanosta*-1(10),9(11)-*dien*-7-*one* (4) which crystallised from ether–methanol as needles (110 mg), m.p. 130—131.5 °C, $[\alpha]_D$ +24.5°, $\lambda_{max.}$ 296 nm (ε 38) with strong end-absorption; $\nu_{max.}$ 1 735, 1 274 (OAc), 1 698 (ketone), and 1 668 cm^{-1} (C=C); δ 5.4 (2 H, m, 1-H and 11-H), 4.75 (1 H, dd, *J* 6 and 10 Hz, 3-H), and 2.04 (3 H, s, OAc); *m/e* 482 (M^+, 27%), 467 (11), 440 (77), 422 (100), 407 (43), 381 (30), 380 (36), 379 (27), 369 (25), 327 (18), 309 (27), 301 (25), 261 (64), 147 (34), 145 (32), 133 (25), 119 (75), 105 (41), 95 (32), and 69 (34) (Found: C, 79.6; H, 10.7%; M^+, 482.367 3. $C_{32}H_{50}O_3$ requires C, 79.6; H, 10.4%. M^+, 482.376 0). Elution with ether–light petroleum (3 : 200) yielded 3β-*acetoxy*-9a-*homo*-19-*norlanosta*-9a(10),9(11)-*dien*-7-*one* which crystallised from methanol as needles (4 mg), m.p. 171—172 °C, $[\alpha]_D$ +262°, $\lambda_{max.}$ 238 nm (ε 19 200) (with shoulders at 232 and 243 nm, ε 13 300 and 13 500 respectively); $\nu_{max.}$ 1 735, 1 265 (OAc), and 1 705 cm^{-1} (ketone); δ 6.20 (1 H, s, $W_{\frac{1}{2}}$ 4 Hz, 9a-H), 5.71 (1 H, m, 11-H), 4.50 (1 H, dd, *J* 5 and 12 Hz, 3-H), and 2.05 (3 H, s, OAc); *m/e* 482 (M^+, 12%), 422 (100), 407 (80), 394 (25), 390 (23), 379 (35), 377 (30), 309 (30), 281 (20), 267 (32), 253 (28), 239 (45), 223 (35), 211 (37), 197 (28), 185 (30), 171 (38), 159 (32), 157 (32), 145 (35), 133 (28), 121 (37), 119 (47), 109 (38), 107 (40), 105 (38), 95 (57), 81 (45), and 69 (67) (Found: C, 79.7; H, 10.7. $C_{32}H_{50}O_3$ requires C, 79.6; H, 10.4%). Elution with ether–light petroleum (1 : 25) gave 3β-acetoxylanostane-7,11-dione (120 mg) identified by comparison (m.p., mixed m.p., i.r. spectrum) with an authentic specimen. Elution with ether–light petroleum (1 : 10) gave 3β-*acetoxy*-11β-*hydroxy*-19(10→9β)abeo-*lanost*-1(10)-*en*-7-*one* (5a) which crystallised from methanol as needles (16 mg), m.p. 180—182 °C, $[\alpha]_D$ −6°, $\nu_{max.}$ (Nujol) 3 470 (OH), 1 750, 1 260 (OAc), and 1 695 cm^{-1} (ketone); δ 5.67 (1 H, m, 1-H), 4.80 (1 H, m, 3-H), 4.39 (1 H, m, 11-H), 2.62 (1 H, s, 8-H), and 2.04 (3 H, s, OAc); *m/e* 500 (M^+, 1%), 438 (11), 423 (25), 422 (25), 407 (64), 309 (14), 291 (13), 267 (14), 241 (23), 239 (27), 225 (26), 207 (51), 189 (100), 173 (64), 133 (61), 121 (91), 119 (70), 109 (70), 107 (59), and 105 (78) (Found: C, 77.0; H, 10.6. $C_{32}H_{52}O_4$ requires C, 76.8; H, 10.5%).

3β,11β-*Diacetoxy*-19(10→9β)abeo-*lanost*-1(10)-*en*-7-*one* (5b).— 3β-Acetoxy-11β-hydroxy-19(10→9β)*abeo*-lanost-1(10)-en-7-one (300 mg) prepared above was acetylated by acetic anhydride (10 ml) in pyridine (5 ml) at 100 °C during 2 h. Purification of the product through chromatography on silica gel gave the *diacetate* (5b) as a gum, $[\alpha]_D$ −9°, $\nu_{max.}$ (film) 1 745, 1 250 (OAc), and 1 708 cm^{-1} (ketone); δ 5.94 (1 H, m, 11-H), 5.76 (1 H, m, 1-H), 4.84 (1 H, dd, *J* 6 and 10 Hz, 3-H), 2.09 and 2.07 (2 × 3 H, 2s, 3-OAc and 11-OAc); *m/e* 542 (M^+, 1%) (Found: C, 75.3; H, 9.8. $C_{34}H_{54}O_5$ requires C, 75.2; H, 10.0%).

3β-*Acetoxy*-19(10→9β)abeo-*lanosta*-1(10),11-*dien*-7-*one* (8).—Phosphoryl chloride (0.2 ml) was added to a solution of 3β-acetoxy-11β-hydroxy-19(10→9β)*abeo*-lanost-1(10)-en-7-one (5a) (100 mg) in pyridine (5 ml) and the mixture heated on a steam-bath for 10 min. The reaction mixture was added to ice–water and the product isolated in ether. 3β-*Acetoxy*-19(10→9β)abeo-*lanosta*-1(10),11-*dien*-7-*one* (8) crystallised from methanol as needles (65 mg), m.p. 155.5—156.5 °C, $[\alpha]_D$ −72.5°, $\nu_{max.}$ 1 725, 1 262 (OAc), and 1 700 cm^{-1} (ketone); δ 5.98 (1 H, d, *J* 10 Hz, 11- or 12-H), 5.74 (2 H, m, 1-H and 11- or 12-H), 4.79 (1 H, dd, *J* 6.5 and 11 Hz, 3-H), 2.66 (1 H, s, 8-H), 2.05 (3 H, s, OAc), [δ(C_6D_6) 6.01, 5.61 (each 1 H, d, *J* 10 Hz; 11-H and 12-H), and 5.46 (1 H, m, 1-H)]; *m/e* 482 (M^+, 2%) (Found: C, 79.6; H, 10.3. $C_{32}H_{50}O_3$ requires C, 79.6; H, 10.4%).

Isomerisation of 3β-*Acetoxy*-9a-*homo*-19-*norlanosta*-1(10),-9(11)-*dien*-7-*one* (4).—(*a*) Boron trifluoride–diethyl ether (0.5 ml) and acetic acid (2 ml) were added to a solution of the dienone (4) (100 mg) in benzene (5 ml) and the reaction mixture set aside at room temperature for 4 h. Water was added and the product isolated in ether. Crystallisation from methanol gave 3β-*acetoxy*-9a-*homo*-19-*norlanosta*-1(10),8-*dien*-7-*one* (7a) as needles (90 mg), m.p. 138—139.5 °C, $[\alpha]_D$ −100.5°; $\lambda_{max.}$ 252 nm (ε 8 000); $\nu_{max.}$ 1 734, 1 265 (OAc), and 1 665 cm^{-1} (conjugated ketone); δ 5.44 (1 H, m, 1-H), 4.78 (1 H, dd, *J* 6 and 10 Hz, 3-H), and 2.07

(3 H, s, OAc); *m/e* 482 (M^+, 9%) (Found: C, 79.8; H, 10.4. $C_{32}H_{50}O_3$ requires C, 79.6; H, 10.4%).

(*b*) The dienone (4) (200 mg) was added to 10% methanolic potassium hydroxide (10 ml) and the mixture heated under reflux for 45 min. Water was added and the product isolated in ether; it was acetylated (acetic anhydride–pyridine) and the acetate purified by chromatography (silica gel, 4 g) followed by crystallisation from methanol to give 3β-acetoxy-9a-homo-19-norlanosta-1(10),8-dien-7-one (7a) (90 mg) identical (m.p., mixed m.p., $[\alpha]_D$, u.v. and i.r. spectra) with that prepared in (*a*) above.

When a solution of the above dienone (7a) (100 mg) in acetic anhydride (10 ml) containing toluene-*p*-sulphonic acid (20 mg) was heated on the steam-bath for 2 h it formed the enol acetate, 3β,7-*diacetoxy*-9a-*homo*-19-*norlanosta*-1(10),7,9(11)-*triene*, isolated as a gum (90 mg) after purification by chromatography (silica gel, 2 g), $[\alpha]_D$ +8°, $\lambda_{max.}$ 248 nm (ε 13 500); $\nu_{max.}$ (Nujol) 1 754 and 1 248 cm^{-1} (OAc); δ 5.29 (2 H, m, 1-H and 11-H), 4.83 (1 H, dd, *J* 6 and 10 Hz, 3-H), and 2.17, 2.08 (2 × 3 H, 2s, 2 × OAc); *m/e* 524 (M^+, 10%) (Found: C, 77.8; H, 10.4. $C_{34}H_{52}O_4$ requires C, 77.8; H, 10.0%).

3β-*Acetoxy*-9a-*homo*-19-*norlanosta*-1(10),5,8-*trien*-7-*one* (7b).—Freshly sublimed selenium dioxide (35 mg) was added to a solution of 3β-acetoxy-9a-homo-19-norlanosta-1(10),8-dien-7-one (7a) (100 mg) in acetic acid (15 ml) and the mixture heated on a steam-bath for 15 min. It was poured into water, the product isolated in ether and purified by chromatography (silica gel, 2 g). 3β-*Acetoxy*-9a-*homo*-19-*norlanosta*-1(10),5,8-*trien*-7-*one* (7b) crystallised from methanol as yellow needles (85 mg), m.p. 171—172 °C, $[\alpha]_D$ −115°, $\lambda_{max.}$ 297 nm (ε 14 000); $\nu_{max.}$ 1 730, 1 263 (OAc), 1 650 (conjugated ketone), and 1 615 cm^{-1} (C=C); δ 5.94 (1 H, s, $W_{\frac{1}{2}}$ 3 Hz, 6-H), 5.73 (1 H, m, 1-H), 4.76 (1 H, m, 3-H), and 1.93 (3 H, s, OAc); *m/e* 480 (M^+, 32%) (Found: C, 79.7; H, 10.3. $C_{32}H_{48}O_3$ requires C, 80.0; H, 10.1%).

Reduction of 3β-*Acetoxy*-9a-*homo*-19-*norlanosta*-1(10),9(11)-*dien*-7-*one* (7a) *by Sodium Borohydride*.—Sodium borohydride (0.6 g) was added over 4 h to a stirred solution of the dienone (7a) (200 mg) in methanol (20 ml) at room temperature; small quantities of methanol were also added during this period to maintain a clear solution. The solution was stirred for a further 1 h by which time reaction was complete (t.l.c.). The mixture was poured into water, acidified (dilute hydrochloric acid), and the product isolated in ether. Purification by chromatography (silica gel, 2 g) gave 3β-*acetoxy*-9a-*homo*-19-*norlanosta*-1(10),9(11)-*dien*-7ζ-*ol* as a gum (160 mg), $[\alpha]_D$ −27°; $\nu_{max.}$ (Nujol) 3 545 (OH), and 1 728, 1 273 cm^{-1} (OAc); δ 5.45, 5.32 (each 1 H, m; 1-H and 11-H), 4.70 (1 H, m, 3-H), 4.22 (1 H, m, 7-H), 3.07 (2 H, br s, 9a-CH_2), and 2.02 (3 H, s, OAc) *m/e* 484 (M^+, 1%) (Found: C, 79.3; H, 11.1. $C_{32}H_{52}O_3$ requires C, 79.3; H, 10.8%). Acetylation (acetic anhydride–pyridine) gave the diacetate, 9a-*homo*-19-*norlanosta*-1(10),9(11)-*dienedi*-3β,7ζ-*yl diacetate* as a gum, $[\alpha]_D$ −23°, $\nu_{max.}$ 1 735, 1 270 cm^{-1} (OAc); δ 5.36, 5.26 (2 H and 1 H respectively, 2m, 1-H, 7-H and 11-H), 4.70 (1 H, m, 3-H), 3.07br (2 H, s, 9a-CH_2), 2.06 and 2.02 (2 × 3 H, 2s, 3-OAc and 7-OAc); *m/e* 466 (M^+ − AcOH, 11%) (Found: C, 77.7; H, 10.6. $C_{34}H_{54}O_4$ requires C, 77.5; H, 10.3%).

Rearrangement of 3β-*Acetoxy*-9β,11β-*epoxylanostan*-7-*one* (1b) *by Boron Trifluoride–Diethyl Ether in Nitromethane*.—Boron trifluoride–diethyl ether (0.2 ml) was added to a solution of the β-epoxide (1b) (100 mg) in nitromethane (10 ml) and the mixture set aside at room temperature for 1 min. The reaction mixture was added to water, and the nitromethane solution well washed with water and sodium hydrogen carbonate solution, and then dried. Removal of the solvent gave 3β-acetoxylanostane-7,11-dione (80 mg), identical (m.p., mixed m.p., and i.r.) with an authentic specimen.

Rearrangement of 3β-*Acetoxy*-9β,11β-*epoxylanostan*-7-*one* (1b) *by Boron Trifluoride–Diethyl Ether in Acetic Anhydride*.—The β-epoxide (1b) (0.7 g) was dissolved in acetic anhydride (25 ml) by warming and the solution cooled to 0 °C; boron trifluoride–diethyl ether (5 ml) was added and the solution was kept at 0 °C for 5 min. The reaction mixture was poured into water and the product isolated in ether to give an oil which was dissolved in light petroleum and chromatographed on silica gel (14 g). Elution with ether–light petroleum (1 : 100) gave a small amount of unchanged starting material (<5 mg). Elution with ether–light petroleum (2 : 100) gave 3β-acetoxylanostane-7,11-dione (95 mg), identical (m.p., mixed m.p., and i.r.) with an authentic specimen. Elution with diethyl ether–light petroleum (3 : 100) gave 3β,11β-diacetoxy-19(10→9β)-*abeo*-lanost-1(10)-en-7-one (5b) (180 mg) identical (i.r., n.m.r., and mass spectra) with that prepared above. Elution with ether–light petroleum (5 : 100) gave 3β,11β-diacetoxy-19(10→9β)*abeo*-10α-lanost-5-en-7-one (2a) (360 mg) which crystallised from methanol as needles, m.p. 189—190 °C (lit.,[2] 188—190 °C), $[\alpha]_D$ +94.5°, with u.v., i.r., and mass spectra identical with those previously reported.[2]

Hydrolysis of 3β,11β-*Diacetoxy*-19(10→9β)abeo-10α-*lanost*-5-*en*-7-*one* (2a). *Epimerisation at* C-10.—(a) *Partial hydrolysis*. When the diacetate (2a) was hydrolysed with 5% methanolic potassium hydroxide at room temperature for 3 h, the monoacetate, 11β-acetoxy-3β-hydroxy-19-(10→9β)*abeo*-10α-lanost-5-en-7-one (2b), m.p. 215—216 °C (lit.,[2] 214—216 °C) was obtained quantitatively.

(b) *Hydrolysis to the diols* (2c) *and* (2e); *epimerisation at* C-10. The diacetate (2a) (400 mg) was dissolved in 10% ethanolic potassium hydroxide solution (30 ml) and the mixture heated under reflux for 15 min. The reaction mixture was poured into water and the product isolated in diethyl ether. A solution of the crude product in chloroform was added to a column of silica gel (10 g) and developed first with chloroform–benzene (1 : 1) which removed a small amount of amorphous material. Elution with chloroform then gave the 10β-isomer, 3β,11β-*dihydroxy*-19(10→9β)abeo-*lanost*-5-*en*-7-*one* (2e) which crystallised from ether–light petroleum as prisms (200 mg), m.p. 183—185 °C, $[\alpha]_D$ +106°; $\lambda_{max.}$ 247 nm (ε 13 500), $\nu_{max.}$ 3 630, 3 430 (OH), and 1 655 cm^{-1} (conjugated ketone); δ 6.15 (1 H, d, *J* 2 Hz, 6-H), 3.98 (1 H, m, 11-H), 3.48 (1 H, s, OH, disappeared on D_2O exchange), 3.42 (1 H, m, 3-H), 2.47 (1 H, s, 8-H), and 2.16br (1 H, s, OH, disappeared on D_2O exchange); *m/e* 458 (M^+, 15%) (Found: C, 78.4; H, 10.8. $C_{30}H_{50}O_3$ requires C, 78.6; H, 11.0%). Elution with chloroform–methanol (10 : 1) gave the 10α-isomer, 3β,11β-dihydroxy-19(10→9β)*abeo*-10α-lanost-5-en-7-one (2c) which crystallised from chloroform–methanol as prisms (120 mg), m.p. 235—236 °C (lit.,[2] 230—233 °C). Hydrolysis of the monoacetate (2b) under the same conditions gave the same mixture of diols (2c) and (2e).

3β-*Acetoxy*-11β-*hydroxy*-19(10→9β)abeo-*lanost*-5-*en*-7-*one* (2f).—The diol 3β,11β-dihydroxy-19(10→9β)*abeo*-lanost-5-en-7-one (2e) was acetylated by acetic ahydride–pyridine at room temperature for 3 h to give the mono-

acetate 3β-*acetoxy*-11β-*hydroxy*-19(10→9β)abeo-*lanost*-5-*en*-7-*one* (2f) in quantitative yield. It crystallised from methanol as needles, m.p. 234—235 °C, $[\alpha]_D$ +87.5°; $\lambda_{max.}$ 243 nm (ε 13 500), $\nu_{max.}$ (Nujol) 3 540 (OH), 1 735, 1 260 (OAc), and 1 665 cm^{-1} (conjugated ketone); δ 6.15 (1 H, s, 6-H), 4.58 (1 H, dd, *J* 5 and 10 Hz, 3-H), 3.96 (1 H, s, $W_{\frac{1}{2}}$ 7 Hz, 11-H), 2.57 (1 H, s, 8-H), and 2.07 (3 H, s, OAc); *m/e* 500 (M^+, 7%) (Found: C, 76.7; H, 10.3. $C_{32}H_{52}O_4$ requires C, 76.8; H, 10.5%).

3β,11β-*Diacetoxy*-19(10→9β)abeo-*lanost*-5-*en*-7-*one* (2g).—The monoacetate (2f) above was acetylated by heating its solution in acetic anhydride–pyridine for 4 h on a steam-bath to give the diacetate 3β,11β-*diacetoxy*-19-(10→9β)abeo-*lanost*-5-*en*-7-*one* (2g) in quantitative yield; it crystallised from methanol as needles, m.p. 256—257 °C, $[\alpha]_D$ +71°; $\lambda_{max.}$ 243 nm (ε 13 500); $\nu_{max.}$ 1 735, 1 260 (OAc), and 1 665 cm^{-1} (conjugated ketone); δ 6.14 (1 H, d, *J* 1.5 Hz, 6-H), 5.18 (1 H, br s, 11-H), 4.64 (1 H, dd, *J* 5 and 10 Hz, 3-H), 2.61 (1 H, s, 8-H), 2.08 and 2.05 (2 × 3 H, 2s, 2 × OAc); *m/e* 542 (M^+, 5%) (Found: C, 75.2; H, 10.3. $C_{34}H_{54}O_5$ requires C, 75.2; H, 10.0%).

11β-*Acetoxy*-3β-*hydroxy*-19(10→9β)abeo-*lanost*-5-*en*-7-*one* (2h).—The diacetate (2g) was hydrolysed by 10% methanolic potassium hydroxide at room temperature for 3 h to give the monoacetate 11β-*acetoxy*-3β-*hydroxy*-19(10→9β)abeo-*lanost*-5-*en*-7-*one* which crystallised from methanol as needles (80% yield), m.p. 198—200 °C, $[\alpha]_D$ +85.5°; $\lambda_{max.}$ 245 nm (ε 13 500); $\nu_{max.}$ 3 645, 3 475 (OH), 1 740, 1 270 (OAc), and 1 670 cm^{-1} (conjugated ketone); δ 6.16 (1 H, d, *J* 1.5 Hz, 6-H), 5.28 (1 H, m, 11-H), 3.40 (1 H, dd, *J* 5 and 10 Hz, 3-H), 2.60 (1 H, s, 8-H), and 2.06 (3 H, s, OAc); *m/e* 500 (M^+, 30%) (Found: C, 76.7; H, 10.3. $C_{32}H_{52}O_4$ requires C, 76.8; H, 10.5%).

Rearrangement of 3β-*Acetoxy*-9α,11α-*epoxylanostan*-7-*one* (1a) *by Boron Trifluoride–Diethyl Ether*.—(a) *In benzene*. Boron trifluoride–diethyl ether (0.5 ml) was added to a solution of the α-epoxide (1a) (100 mg) in dry benzene (2 ml) and the reaction mixture set aside at room temperature for 10 days. The product was isolated by addition of the reaction mixture to water and extraction with ether. The oily product was dissolved in light petroleum and chromatographed on silica gel (2 g). Elution with diethyl ether–light petroleum (1 : 50) gave unchanged starting material (30 mg), followed by elution with diethyl ether–light petroleum (1 : 25) which gave 3β-*acetoxy*-9β-*lanostane*-7,11-*dione* which crystallised from methanol as needles (50 mg), m.p. 207—209 °C, $[\alpha]_D$ +110.5°; $\nu_{max.}$ 1 735, 1 265 (OAc), and 1 705 cm^{-1} (ketone); δ 4.78 (1 H, m, 3-H) and 2.01 (3 H, s, OAc); *m/e* 500 (M^+, 30%) (Found: C, 77.1; H, 10.7. $C_{32}H_{52}O_4$ requires C, 76.8; H, 10.5%). 3β-Acetoxy-9β-lanostane-7,11-dione (65 mg) was dissolved in 10% methanolic sodium hydroxide (20 ml) and the solution heated under reflux for 12 h; the product was acetylated (acetic anhydride–pyridine) to give 3β-acetoxylanostane-7,11-dione which was identical (m.p., mixed m.p., and i.r.) with an authentic specimen.

(b) *In nitromethane*. Boron trifluoride–diethyl ether (0.1 ml) was added to a solution of the α-epoxide (1a) (100 mg) in nitromethane and the reaction mixture kept at room temperature for 2 h. Work-up as above gave 3β-acetoxy-9β-lanostane-7,11-dione (75 mg) identical (m.p., mixed m.p., i.r.) with that prepared in (a) above.

(c) *In acetic anhydride*. Boron trifluoride–diethyl ether (1 ml) was added to a solution of the α-epoxide (1a) (100 mg) in acetic anhydride (3 ml; warming was necessary to effect solution) at 0 °C, and the reaction mixture maintained at 0 °C for 5 min. The product was isolated as above and purified by filtering its solution in light petroleum through silica gel (2 g). Crystallisation from methanol gave needles (70 mg) of 3β-*acetoxy*-18(13→12β)abeo-*lanosta*-8,13(17)-*dien*-7-*one* (6), m.p. 135—136 °C, $[\alpha]_D$ −53.5°; $\lambda_{max.}$ 249 nm (ε 12 000); $\nu_{max.}$ 1 730, 1 260 (OAc), and 1 660 cm^{-1} (conjugated ketone); δ 4.52 (1 H, dd, *J* 5 and 9 Hz, 3-H) and 2.06 (3 H, s, OAc); *m/e* 482 (M^+, 20%), 467 (6), 369 (100), 355 (5), 309 (28), 173 (46), 159 (10), 145 (10), 121 (16), 107 (12), and 69 (18) (Found: C, 79.5; H, 10.7. $C_{32}H_{50}O_3$ requires C, 79.6; H, 10.4%). A solution of 3β-acetoxy-18(13→12β)*abeo*-lanosta-8,13(17)-dien-7-one (6) (100 mg) and sulphuric acid (1 drop) in isopropenyl acetate (7 ml) was heated on a steam-bath for 1 h. The product was purified by chromatography on silica gel (2 g) to give the enol acetate, 3β,7-*diacetoxy*-18(13→12β)abeo-*lanosta*-6,8,13(17)-*triene* which crystallised from methanol as needles (80 mg), m.p. 125—126 °C, $[\alpha]_D$ −60°; $\lambda_{max.}$ 262 nm (ε 4 000); $\nu_{max.}$ 1 760, 1 730, and 1 260 cm^{-1} (2 × OAc); δ 5.35 (1 H, d, *J* 3 Hz, 6-H), 4.56 (1 H, dd, *J* 6 and 10 Hz, 3-H), 2.55 (1 H, d, *J* 3 Hz, 5-H), 2.21 (3 H, s, 7-OAc), and 2.06 (3 H, s, 3-OAc); *m/e* 524 (M^+, 4%) (Found: C, 77.8; H, 10.3. $C_{34}H_{52}O_4$ requires C, 77.8; H, 10.0%).

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