# SPONTANEOUS TRANSANNULAR REACTION IN $\Delta^9$-UNSATURATED A-HOMO-B,19-DINORSTEROIDS*

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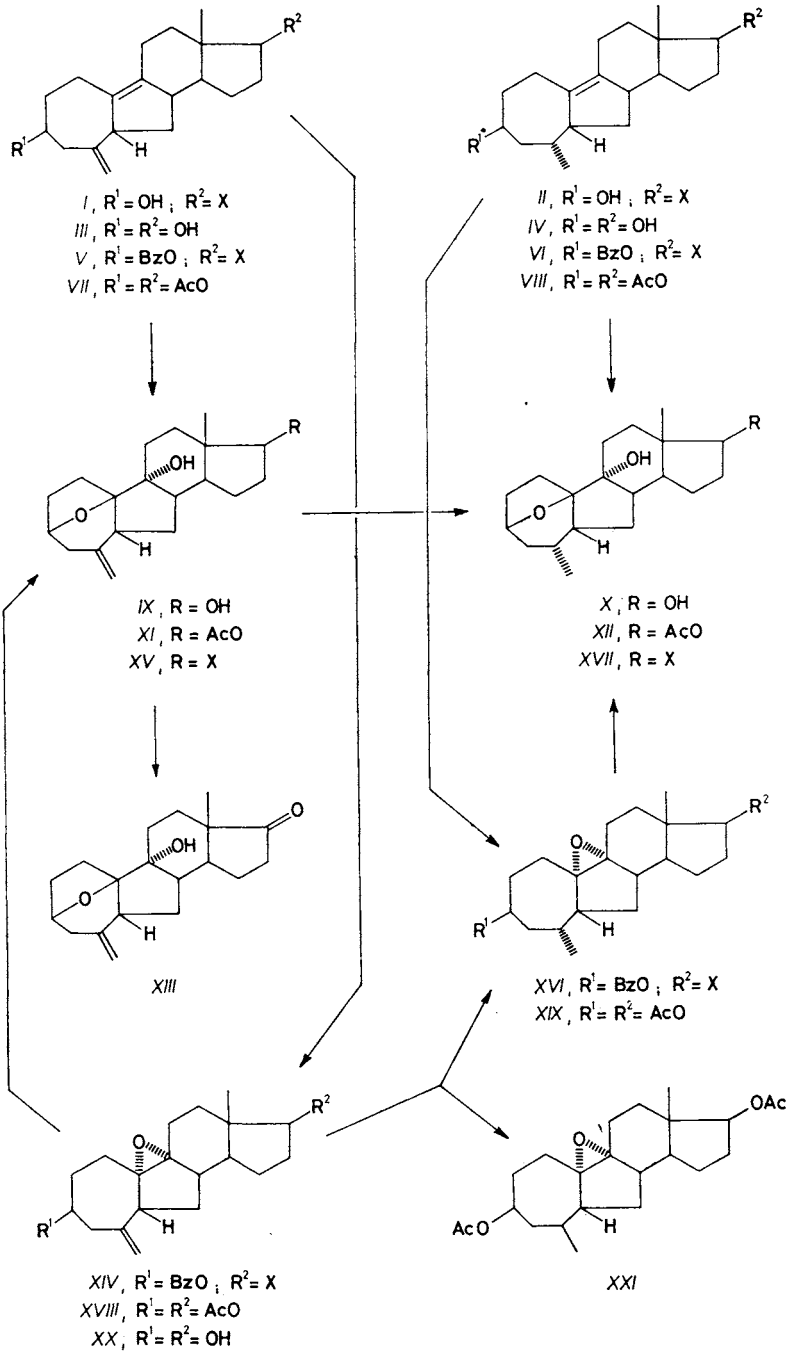
Received September 1, 1988
Accepted October 19, 1988

The epoxidation of 3β-hydroxy derivatives of $\Delta^9$-unsaturated A-homo-B,19-dinorsteroids (type *I*—*IV*) proceeds with spontaneous participation of the 3β-hydroxyl under formation of transannular 9α-hydroxy-3β,10β-oxides *IX*, *X*, *XV* and *XVII*. Epoxidation of the corresponding esters *V*—*VIII* affords predominantly 9α,10α-epoxides *XIV*, *XVI*, *XVIII* and *XIX* which, after hydrolysis of the ester groups are also converted into the transannular 3β,10β-oxides of the type *IX*.

Hydrogenolysis of 6β-chloro derivatives of the Westphalen type (e.g. 3β-acetoxy-6β-chloro-5-methyl-19-nor-5β-cholest-9-ene) with lithium aluminium hydride[1] leads to mixtures of chromatographically very similar dienes and olefins of the type *I* and *II*, respectively. The dienes *I* are very sensitive to oxidation: they are spontaneously oxidized with air oxygen to give peroxides. Consequently, separation procedures, such as chromatography on $AgNO_3$-treated silica gel, are accompanied by unproportional losses; this precludes to evaluate the extent of elimination with rearrangement on the one hand (formation of compounds of the type *I*) and substitution by hydride ion with rearrangement on the other hand (formation of the type *II*). We treated therefore the mixture of compounds *III* and *IV* (ref.[2]) with one equivalent of *m*-chloroperoxybenzoic acid, expecting that the formed epoxides will be sufficiently stable to allow further separation. However, the epoxidation afforded two new products (*IX* and *X*) that were substantially less polar and contained one oxygen atom more (mass spectrometry) than the starting compounds *III* and *IV*. As shown by $^1$H NMR as well as infrared spectra of the product *IX*, the exo-methylene group remained intact but no signals indicating the presence of an epoxide grouping occured. The 3α-H signal in $^1$H NMR spectra of both compounds had different chemical shift and multiplicity compared with the spectra of compounds *I* and *II*. All these data can be explained by preferential epoxidation of the $\Delta^9$-double bond from the less hindered α-side with a transannular participation of the 3β-hydroxy group. According to

* Part CCCILII in the series On Steroids; Part CCCILI: Collect. Czech. Chem. Commun. *54*, 1318 (1989).




In formulae *I*–*XXI*: X = $CH(CH_3)(CH_2)_3CH(CH_3)_2$ ; Ac = $CH_3CO$ ; Bz = $C_6H_5CO$

the rules for epoxide opening[3], the newly arising hydroxyl group should have the 9α-position. This structure is compatible both with the low polarity of products *IX* and *X* (instead of the accessible 3β-hydroxyl, the molecule of *IX* contains the sterically hindered 9α-hydroxyl) and chemical properties: compounds *IX* and *X* were acetylated only to the monoacetates *XI* and *XII* or oxidized to ketones with one unreactive hydroxy group (*XIII*). The presence of a transannular oxide bridge in compounds of the type *XV* and *XVII* has been confirmed by $^{13}C$ NMR spectra: in addition to the C-3 signal, the spectrum exhibits two other signals of atoms (C-9 and C-10) bonded to oxygen atoms. Their quaternary character was confirmed by the "attached proton test" method[4] (APT).

In accord with this concept of epoxidation of 3β-hydroxy derivatives *I–IV*, the epoxidation of 3β-acyloxy derivatives of this series (*V–VIII*) proceeded without complications. Epoxidation of the authentic[1] benzoate *V* afforded the 9α,10α-epoxide *XIV* as the principal product (whose structure was confirmed by reduction with lithium aluminium hydride) which on acidic work-up was transformed quantitatively into the transannular oxide *XV* (in the 9β,10β-epoxide no such interaction with the 3β-hydroxy group could take place). Similarly, the epoxidation of 3β-benzoate *VI* (prepared from the authentic[1] olefin *II*) led to 9α,10α-epoxide *XVI* which again was spontaneously converted into the corresponding transannular oxide *XVII* after liberation of the 3-hydroxy group.

The mixture of the androstane olefin *III* and diene *IV* (ref.[2]) was acetylated and epoxidized: this converted the originally chromatographically unseparable mixture into two compounds containing one more oxygen atom (*XVIII* and *XIX*). The lipophilic product contained (IR, $^1H$ NMR spectra) an exomethylene group and was therefore the unsaturated epoxide *XVIII*, the polar one exhibited signals of a $CH_3$—CH grouping in the $^1H$ NMR spectrum and was assigned the saturated epoxide structure *XIX*.

The hydrolysis of the ester groups in compounds *XVIII* and *XIX* was followed using two-dimensional TLC: it was shown that acid hydrolysis of e.g. compound *XVIII* gives the transannular oxide *IX* as the only detectable product (along with the unchanged starting compound) from the very beginning. On the other hand, alkaline hydrolysis gives originally another compound (*XX*) which is converted into the transannular epoxide *IX* only by acidity of the silica gel. Whereas working under strictly neutral conditions allowed isolation of this hydroxy-epoxide *XX*, a mere filtration of its chloroform solution through sodium sulfate was sufficient to induce the isomerisation to compound *IX*.

To verify the structure of both series of derivatives (saturated as well as with the exomethylene double bond), we hydrogenated the unsaturated transannular oxides *IX* and the epoxides *XVIII* and compared the hydrogenation products with the corresponding saturated products *X* and *XIX*. It appeared that in the first case the hydrogenation proceeds stereospecifically from the β-side, affording compounds

identical with the saturated oxides of the type *X*; this is obviously caused not only by the overall conformation of the system but also by the fact that the oxide bridge, capable of bonding to the platinum catalyst, is situated on the same β-side of the molecule. In contrast, the hydrogenation of unsaturated epoxides of the type *XVIII* proceeds with much lower stereospecificity ($^1$H NMR spectra of mother liquors after crystallisation of the products (e.g. *XIX*) revealed the presence of another compound, probably the isomer *XXI* with the opposite configuration on C-4a); this lower β-side stereospecificity is apparently due to the fact that the epoxide bridge in question is on the opposite α-side of the molecule.

The easiness of the described transannular participation of the 3β-hydroxy group in epoxidation of the $\Delta^9$-bond in compounds of the type *I* and *II* may be better understood on inspection of Fig. 1 which depicts one of the conformers of ring A in these compounds. The formation of oxides *IX* and *X* in epoxidation of the mixture *III* + *IV* enabled us to estimate the content of the product of hydrogenolysis with rearrangement (*IV*; 15%) in the product of elimination with rearrangement (*III*; 85%).

## EXPERIMENTAL

The melting points were determined on a Kofler block and are uncorrected. Optical rotations and IR spectra (Zeiss UR-20) were measured in chloroform, unless stated otherwise; the wavenumbers are given in $cm^{-1}$. Proton NMR spectra were obtained in deuteriochloroform with tetramethylsilane as internal standard; chemical shifts are in ppm (δ-scale), coupling constants (*J*) and half-height widths (*W*) in Hz. All parameters were obtained by first-order analysis; spectra measured on a Tesla BS-467 instrument (60 MHz; CW mode) are given in Table I, those obtained with a Varian XL-200 spectrometer (200 MHz, FT mode) are given directly in the individual experiments. The identity of compounds, prepared by different routes, was determined by mixture melting points and IR spectra. The reaction course and purity of the samples were

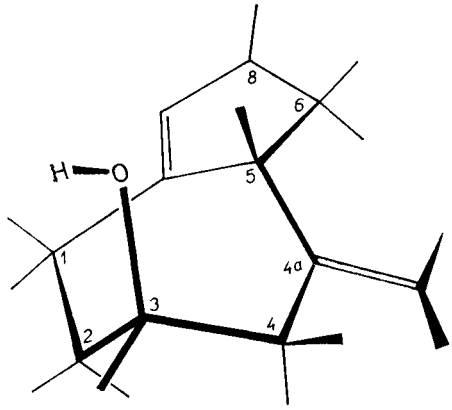



FIG. 1

Conformation of rings A and B in 3β--hydroxy-4a-methyleno-A-homo-B,19-dinor--5β-androst-9-enes

checked by thin-layer chromatography (TLC) on silica gel (Woelm DC; detection with sulfuric acid and heating), column chromatography was performed on silica gel Silpearl (Kavalier, Votice).

3β-Benzoyloxy-4aα-methyl-A-homo-B,19-dinor-5β-cholest-9-ene (*VI*)

Freshly prepared[1] olefin *II* (96 mg) was dried by coevaporation with toluene and dissolved in a mixture of pyridine (0·3 ml) and benzoyl chloride (0·15 ml). After standing in an argon atmosphere for 1 h, the mixture was poured into water, the product was taken up in chloroform and the extract was washed successively with dilute hydrochloric acid, water, potassium carbonate solution and again with water, all these operations being performed under argon. The extract was dried over sodium sulfate and concentrated in vacuo. The dry product was purified by TLC ($R_F$ 0·6) in a mixture of light petroleum–benzene (1 : 1), affording 101 mg (83%) of *VI*. For $C_{34}H_{50}O_2$ (490·7) calculated: 83·21% C, 10·27% H; found: 82·98% C, 10·40% H.

TABLE I

Characteristic parameters of 60 MHz NMR spectra[a]

| Compound | 18-H[b] | 4b-H | 3-H | 17-H | Other signals[c] |
|---|---|---|---|---|---|
| *I* | 0·74 | 4·84[d] | 3·70[e] | [f] | 3·25[g] |
| *II* | 0·75 | 0·92[h] | 3·81[e] | [f] | |
| *III* | 0·84 | 4·81[d] | 3·63[i] | 3·63[i] | 3·30[g] |
| *V* | 0·76 | 4·94[d] | 4·87[e] | [f] | 3·38[g], 7·48[h], 8·05[h] |
| *VII* | 0·88 | 4·93[d] | 4·80[e] | 4·53[l] | 2·02[m], 2·03[m], 3·36[g] |
| *IX*[j] | 0·83 | [f] | 3·90[k] | 3·56[l] | |
| *X* | 0·82 | 0·89[h] | 3·87[k] | 3·54[l] | |
| *XI* | 0·91 | 4·79[i] | 3·94[k] | 4·61[i] | 2·03[m] |
| *XII* | 0·89 | 0·87[h] | 3·90[k] | 4·62[l] | 2·01[m] |
| *XIII* | 1·23 | 4·76[d] | 3·95[k] | — | |
| *XIV* | 0·76 | 4·98[d] | [f] | [f] | 7·47[h], 8·05[h] |
| *XV* | 0·79 | 4·74[d] | 3·94[k] | [f] | |
| *XVI* | 0·78 | 1·04[h] | 5·15[e] | [f] | 7·48[n], 8·06[n] |
| *XVII* | 0·77 | 0·88[h] | 3·88[k] | [f] | |
| *XVIII* | 0·92 | 4·97[d] | 4·65[i] | 4·65[i] | 2·94[o], 2·05[m] |
| *XIX* | 0·90 | 0·95[h] | 4·98[e] | 4·68[l] | 2·03[m], 2·05[m] |

[a] 200 MHz spectra are given in the description of preparation of the pertinent compounds in the Experimental part; [b] singlet, 3 H; [c] in addition, cholestane derivatives exhibit signals of the side-chain methyl groups (0·85 d, 6 H (3 × H-26 and 3 × H-27, $J$ = 6·5)) and 0·91 d, 3 H (3 × H-21, $J$ = 6·5); [d] narrow m, 2 H ($W_{1/2}$ = 6); [e] m ($W_{1/2}$ = 27); [f] signal obscured by other signal; [g] broad t, 1 H (5-H, $J$ = 8); [h] d, 3 H ($J$ = 6·5); [i] overlapping signals; [j] because of low solubility in $CDCl_3$ measured in $CD_3OH$; in $CD_3SOCD_3$: 0·70 s, 3 H (3 × H-18); 4·67 m, 1 H (H-4b, $W_{1/2}$ = 8); [k] m ($W_{1/2}$ = 13—14); [l] t ($W_{1/2}$ = 8); [m] s, 3 H ($CH_3COO$); [n] m, protons of benzoyloxy group; [o] t, 1 H (H-5, $J$ = 5).

Mixture of 3β,17β-Diacetoxy-4a-methyleno-B,19-dinor-5β-androst-9-ene (*VII*) and 3β,17β-Diacetoxy-4aα-methyl-B,19-dinor-5β-androst-9-ene (*VIII*)

A mixture of *III* and *IV* (1 g), freshly prepared[2] by hydrogenolysis of 3β,17β-diacetoxy-6β-chloro--5-methyl-19-nor-5β-androst-9-ene[4], was acetylated with acetic anhydride (3 ml) and pyridine (5 ml) under argon. After 18 h the mixture was diluted with water, the product was extracted with chloroform and the extract was washed successively with dilute hydrochloric acid, water, aqueous potassium hydrogen carbonate and water, and dried over sodium sulfate. All the operations were performed under argon. Evaporation of the solvent afforded 1·08 g of crude mixture of *VII* and *VIII*; TLC: $R_F$ 0·75 (ether–benzene 1 : 3). IR spectrum: 3 080, 1 651, 1 644, 899 (C=$CH_2$); 1 744, 1 251, 1 045, 1 031 ($CH_3COO$).

4-Methyleno-3β,10-oxido-A-homo-B,19-dinor-5β-androstane-9α,17β-diol (*IX*)

*A*) *From the mixture* of III *and* IV. *m*-Chloroperoxybenzoic acid (1 g) was added at −18°C to a stirred solution of freshly prepared[2] mixture of *III* and *IV* (1·6 g) in chloroform (10 ml). After 10 min the mixture was diluted with chloroform, washed with aqueous potassium hydrogen carbonate and water and dried over sodium sulfate. The solvent was evaporated in vacuo and the residue was purified by chromatography on silica gel in toluene–ether (1 : 1) mixture. The principal product was crystallized from toluene–acetone, yield 863 mg (51%) of *IX*, m.p. 236–240°C; $[\alpha]_D$ −143° (*c* 0·7, $CH_3OH$). IR spectrum (KBr): 3 385 (OH); 1 090, 1 083, 1 069, 1 048, 1 019, 999 (—O—); 3 080, 1 650, 1 643, 900 (C=$CH_2$). For $C_{19}H_{28}O_3$ (304·4) calculated: 74·96% C, 9·27% H; found: 74·60% C, 9·33% H.

*B*) *From epoxide* XVIII. Compound *XVIII* (18 mg) was dissolved in 1% methanolic potassium hydroxide. After standing for 18 h, the solution was diluted with water and the product was taken up in chloroform. The extract was washed with water, dried over sodium sulfate and taken down to give 9 mg (63%) of *IX*, m.p. 236–240°C (toluene).

4aα-Methyl-3β,10-oxido-A-homo-B,19-dinor-5β-androstane-9α,17β-diol (*X*)

*A*) *From the mixture of olefins* III *and* IV. More polar chromatographic fractions in the preparation of *IX* afforded 146 mg (8·7%) of compound *X*, m.p. 231–233°C (acetone–heptane); $[\alpha]_D$ −37° (*c* 0·9, $CH_3OH$). IR spectrum (KBr): 3 385, 3 260 (OH); 1 090, 1 063, 1 034, 1 021, 1 010 (—O—). For $C_{19}H_{30}O_3$ (306·4) calculated: 74·47% C, 9·87% H; found: 74·60% C, 9·33% H.

*B*) *From epoxide* XIX. Compound *XIX* (32 mg) was dissolved in a mixture of chloroform (1 ml) and methanol (10 ml) and acidified with concentrated hydrochloric acid (0·2 ml). After standing for 18 h the mixture was concentrated in vacuo to one quarter of the original volume, diluted with ether, washed with water and potassium hydrogen carbonate solution and dried over sodium sulfate. The residue was purified by TLC (6 plates, 200 × 200 × 0·3 mm); yield 17 mg (68%) of *X*.

*C*) *From unsaturated oxide* IX. A suspension of compound *IX* (90 mg) in acetic acid (8 ml) was hydrogenated over Adams catalyst (24 mg). After 4 h the catalyst was filtered off, the filtrate was concentrated in vacuo and the residue was crystallized from acetone to give 64 mg (71%) of *X*.

17β-Acetoxy-4a-methyleno-3β,10-oxido-A-homo-B,19-dinor-5β-androstan-9α-ol (*XI*)

A solution of diol (60 mg) in pyridine (2 ml) and acetic anhydride (1 ml) was set aside at room temperature. After 18 h the mixture was diluted with water (10 ml), the product was extracted with chloroform and the extract washed successively with dilute hydrochloric acid, water, potas-

sium hydrogen carbonate solution and water. After drying over sodium sulfate, the solvent was evaporated and the residue was crystallized from acetone to afford 48 mg (70%) of *XI*, m.p. 234–236°C; $[\alpha]_D$ −107° (*c* 1·5). IR spectrum: 3 605 (OH); 3 080, 1 651, 1 643, 904 (C=$CH_2$); 1 729, 1 263 ($CH_3COO$); 1 084, 1 051, 1 023 (—O—). For $C_{21}H_{30}O_4$ (346·5) calculated: 72·80% C, 8·73% H; found: 72·66% C, 8·70% H.

17β-Acetoxy-4aα-methyl-3β,10-oxido-A-homo-B,19-dinor-5β-androstan-9α-ol (*XII*)

*A) By hydrogenation of methylene derivative* XI. A suspension of compound *XI* (140 mg) in acetic acid (3 ml) was hydrogenated over Adams catalyst (20 mg) at room temperature. After 30 min the catalyst was filtered, washed and the filtrate was concentrated in vacuo. Yield 126 mg (90%) of *XII*, m.p. 218–219°C (acetone); $[\alpha]_D$ −43° (*c* 1·7). IR spectrum: 3 605 (OH); 1 729, 1 250 ($CH_3COO$). For $C_{21}H_{32}O_4$ (348·5) calculated: 72·38% C, 9·26% H; found 72·18% C, 9·23% H.

*B) From 17β-hydroxy derivative* X. A solution of compound *X* (60 mg) in warm pyridine (0·5 ml) was diluted with acetic anhydride (0·5 ml) and the mixture was heated to 65°C to keep the product dissolved. After 3 h the mixture was cooled, the product was filtered and washed with acetone. Yield 33 mg (48%) of *XII*, m.p. 218–219°C.

9α-Hydroxy-4a-methyleno-3β,10-oxido-A-homo-B,19-dinor-5β-androstan-17-one (*XIII*)

Dihydroxy derivative *IX* (60 mg) was dissolved in a warm mixture of acetone (5 ml) and toluene (2 ml) and Jones reagent was added to this solution at 45°C. After 3 min the mixture was poured into a solution of potassium hydrogen carbonate, the product was taken up in chloroform and the extract was repeatedly washed with water and dried. The solvent was evaporated, leaving ketone *XIII* (43 mg, 72%), m.p. 252–253°C (acetone-toluene); $[\alpha]_D$ −45° (*c* 1·2). IR spectrum: 3 605 (OH); 1 736 (C=O); 3 080, 1 651, 1 643, 904 (C=$CH_2$). For $C_{19}H_{26}O_3$ (302·4) calculated: 75·46% C, 8·67% H; found: 75·13% C, 8·41% H.

3β-Benzoyloxy-4a-methyleno-9α,10α-oxido-A-homo-B,19-dinor-5β-cholestane (*XIV*)

*m*-Chloroperoxybenzoic acid (180 mg) was added at −18°C to a solution of diene *V* (400 mg; ref.[1]) in chloroform (3 ml). The mixture was set aside at room temperature for 10 min, diluted with chloroform and washed with aqueous potassium hydrogen carbonate and water. After drying over sodium sulfate the solvent was evaporated, affording 232 mg (56%) of *XIV*, m.p. 101–102°C (methanol); $[\alpha]_D$ −11° (*c* 0·9). IR spectrum ($CCl_4$): 1 720, 1 274 ($C_6H_5COO$); 3 075, 1 642, 902 (C=$CH_2$). Mass spectrum, *m/z*: 504 ($M^+$), 486 ($M^+ - H_2O$), 382 ($M^+ - C_6H_5$.COOH). For $C_{34}H_{48}O_3$ (504·7) calculated: 80·90% C, 9·59% H; found: 80·71% C, 9·68% H.

4a-Methyleno-3β,10-oxido-A-homo-B,19-dinor-5β-cholestan-9-ol (*XV*)

A) *From epoxide* XIV. A solution of *XIV* (140 mg) in tetrahydrofuran (5 ml) was refluxed with lithium aluminium hydride (about 250 mg) for 2 h. After cooling, the excess hydride was destroyed first with moist ether and then with several drops of saturated aqueous solution of sodium sulfate. The mixture was saturated with anhydrous sodium sulfate, the inorganic material was filtered and washed with chloroform. The filtrate was washed and taken down in vacuo, the residue was purified by TLC; yield of *XV* was 96 mg (86%); m.p. 197–198°C (methanol); $[\alpha]_D$ −77° (*c* 1·1). IR spectrum: 3 600 (OH); 3 075, 1 642, 900 (C=$CH_2$); 1 051, 1 023 (—O—). Mass spectrum, *m/z*: 400 ($M^+$), 385 ($M^+ - CH_3$), 382 ($M^+ - H_2O$). The compound was stable

under conditions of Jones oxidation and acetylation in pyridine. $^1$H NMR spectrum: 0·79 s, 3 H (3 × H-18); 0·856 d and 0·860 d, 6 H (3 × H-26 and 3 × H-27, $J$ = 6·6); 0·893 d, 3 H (3 × H-21, $J$(20, 21) = 6·6); 4·69 t, 1 H (H-4b, $J$(4, 4bα) = 2·1; $J$(4bα, 4bβ) = 2·4); 4·78 t, 1 H (H-4β, $J$(4, 4bβ) = 2·0; $J$(4bα, 4bβ) = 2·4); 3·95 m, 1 H (H-3α, $\sum J$ = 13·8); 2·73 bdd, 1 H (H-5β, $J$(5β, 6α) = 9·0; $J$(5β, 6β) = 3·4); 2·64 dt, 1 H (H-4α, $J$(4α, 4bα) = 2·1; $J$(4α, 4bβ) = 2·0; $J$(4α, 4β) = −15·2); 2·16 ddd, 1 H (H-4β, $J$(4β, 3α) = 4·1; $J$(4β, 5β) = 1·5; $J$(4α, 4β) = −15·2). For $C_{27}H_{44}O_2$ (400·6) calculated: 80·94% C, 11·07% H; found: 81·06% C, 11·15% H.

*B) From diene* I. *m*-Chloroperoxybenzoic acid (20 mg) was added at −18°C to a solution of diene *I* (ref.[2]; 45 mg) in chloroform (0·5 ml). After standing for 5 min the mixture was diluted with chloroform, washed with a potassium carbonate solution and water, dried over sodium sulfate and the solvent was evaporated. Purification by TLC (1 plate 200 × 200 × 0·3 mm) in benzene afforded 27 mg (58%) of *XV*, m.p. 197–198°C (methanol).

3β-Benzoyloxy-4aα-methyl-9α,10-oxido-A-homo-B,19-dinor-5β,10α-cholestane (*XVI*)

*m*-Chloroperoxybenzoic acid (100 mg) was added at −18°C to a solution of olefin *VI* (ref.[1]; 150 mg) in chloroform (2 ml). After standing at room temperature for 10 min, the mixture was worked up as described in the preceding experiment to give *XVI*, m.p. 99–101°C (methanol). IR spectrum ($CCl_4$): 1 719, 1 274 ($C_6H_5COO$). Mass spectrum, $m/z$: 506 ($M^+$). For $C_{34}H_{50}O_3$ (506·7) calculated: 80·58% C, 9·95% H; found: 80·34% C, 9·80% H.

4aα-Methyl-3β,10β-oxido-A-homo-B,19-dinor-5β-cholestan-9α-ol (*XVII*)

*A) From oxide* XVI. A solution of 9α,10α-oxide *XVI* (26 mg) in tetrahydrofuran (3 ml) was treated with lithium aluminium hydride as described in the preparation of *XV*. The same work-up gave 17 mg (82%) of *XVII*, m.p. 194–196°C (methanol); $[\alpha]_D$ −15° (*c* 1·2). IR spectrum ($CCl_4$): 3 605, 1 059 (OH); 1 025, 1 000, 901 (—O—). Mass spectrum, $m/z$: 402 ($M^+$), 387 ($M^+ - CH_3$) 384 ($M^+ - H_2O$), 269 ($M^+ - 133$). $^1$H NMR spectrum: 0·77 s, 3 H (3 × H-18); 0·853 d and 0·858 d, 6 H (3 × H-26 and 3 × H-27, $J$ = 6·5); 0·89 d, 3 H (3 × H-21, $J$(20, 21) = 6·5); 0·88 d, 3 H (4aα-$CH_3$, $J$(4a, 4b) = 6·4); 3·88 m, 1 H (H-3α, $\sum J$ = 14·6). $^{13}$C NMR spectrum: 10·98 and 19·19 (C-18 and C-4b), 18·72 (C-21), 22·55 and 22·79 (C-26 and C-27), 27·98 (C-25), 35·64 (C-20), 36·11 (C-22), 23·94 (C-23), 39·49 (C-24), 28·22, 50·33, 54·91, 55·48 and 55·54 (C-4a, C-5, C-7, C-14, C-17), 69·15 (C-3), 83·36 (C-10), 84·06 (C-9), 23·71, 26·06, 26·38, 26·44, 28·41, 30·71, 38·49, 40·86 and 41·83 (C-1, C-2, C-4, C-6, C-11, C-12, C-15, C-16 and C-13). $^{13}$C NMR spectrum after addition of trichloroacetyl isocyanate: C-9 signal shifted to δ 96·85. For $C_{27}H_{46}O_2$ (402·6) calculated: 80·54% C, 11·52% H; found: 80·39% C, 11·27% H.

B) *From olefin* II. Compound *II* (49 mg; freshly prepared and purified by chromatography on $AgNO_3$-treated silica gel[1]) was treated with *m*-chloroperoxybenzoic acid (30 mg) in chloroform at −18°C, as described for the epoxidation of *IX*; yield 36 mg (71%) of *XVII*, m.p. 194 to 196°C (methanol).

*C) From unsaturated oxide* XV. A suspension of *XV* (30 mg) in acetic acid (4 ml) was shaken in a hydrogen atmosphere with Adams catalyst (20 mg). After 2 h the catalyst was filtered off, the filtrate was concentrated in vacuo and the residue was crystallized; yield 16 mg (53%) of *XVII*, m.p. 194–196°C (acetone).

3β,17β-Diacetoxy-4a-methyleno-9α,10-oxido-A-homo-B,19-dinor-5β,10α-androstane (*XVIII*)

*m*-Chloroperoxybenzoic acid (250 mg) was added at −18°C to a mixture of acetates *VII* and *VIII* (450 mg) in chloroform (5 ml), obtained by hydrogenolysis of 3β,17β-diacetoxy-6β-

-chloro-5-methyl-19-nor-5β-androst-9-ene[1] and acetylation. The mixture was worked up as described for preparation of compound *XIV* and the residue was flash-chromatographed on silica gel in an ethyl acetate–toluene (1 : 20) mixture. Compound *XVIII* (255 mg; 54%) was obtained as the principal product, m.p. 164—165°C (acetone–heptane); $[\alpha]_D$ −54° (*c* 1·1). For $C_{23}H_{32}O_5$ (388·5) calculated: 71·10% C, 8·30% H; found: 70·90% C, 8·49% H.

3β,17β-Diacetoxy-4aα-methyl-9α,10-oxido-A-homo-B,19-dinor-5β,10α-androstane (*XIX*)

*A*) The more polar fractions from chromatography in the preceding experiment afforded 49 mg (10%) of a second constituent of the reaction mixture, the epoxide *XIX*, m.p. 134—135°C (heptane); $[\alpha]_D$ −29° (*c* 0·9). IR spectrum ($CCl_4$): 1 732, 1 250, 1 033. For $C_{23}H_{34}O_5$ (390·5) calculated: 70·74% C, 9·78% H; found: 70·52% C, 8·69% H.

*B*) A solution of compound *XVIII* (190 mg) in methanol (10 ml) was shaken in an atmosphere of hydrogen with Adams catalyst (45 mg). After 4 min the catalyst was filtered off, the filtrate was concentrated in vacuo and the residue was crystallized to constant melting point (4×) to give 26 mg (14%) of epoxide *XIX*, m.p. 134—135°C (heptane).

Proof of Existence of 3β,17β-Dihydroxy-4a-methyleno-9α,10-oxido-A-homo-B,19-dinor-5β,10α-androstane (*XX*)

Diacetate *XVIII* (10 mg) was dissolved in 1% methanolic potassium hydroxide (0·5 ml). After standing at room temperature for 20 min, a sample of the mixture was applied onto a thin layer of silica gel, the solvent was removed by a stream of air and the dry plate was developed in a mixture of ether–benzene (1 : 1). The developed plate was dried and after 30 min inserted into the same sovent system so as the flow of the solvents was perpendicular to that in the first chromatography. The compound on the diagonal of this chromatogram was the original product of hydrolysis of diacetate *XVIII* (compound *XX*), the compound outside the diagonal was identical with the transannular oxide *IX* which arose by isomerization of the 3β-hydroxy-9α,10α-epoxide (*XX*) with the acidic adsorbent.

*The authors are indebted to Mrs Michaela Bárová for the technical assistance, the Analytical Laboratory (Dr V. Pechanec, Head) for the elemental analyses, Dr J. Smolíková for measurement and interpretation of the* IR *spectra and the Laboratory of Mass Spectrometry (Dr K. Ubík, Head) for taking the mass spectra.*

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Translated by M. Tichý.