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The scope and limitations of the reaction of Δ^5-steroids with mercury(II) trifluoroacetate

Peter L. D. Ruddock,* David J. Williams,† and Paul B. Reese*

**Chemistry Department, University of the West Indies, Mona, Kingston 7, Jamaica; and †Chemical Crystallography Laboratory, Chemistry Department, Imperial College of Science, Technology and Medicine, South Kensington, London, United Kingdom*

The effect of the C-3 substituent on the reaction of androst-5-enes with mercury(II) trifluoroacetate in dichloromethane (modified Treibs oxidation) was investigated. 3β-Acyloxyandrost-5-en-17-ones gave 3β-acyloxy-6β-hydroxyandrost-4-en-17-ones accompanied by 3β-acyloxy-6-chloromercuriandrost-5-en-17-ones. 3β-Acetoxy-6β-trifluoroacetoxyandrost-4-en-17-one and 3β-acetoxy-4β-trifluoroacetoxyandrost-5-en-17-one were revealed to be intermediates in the reaction. The formation of the chloromercury steroids indicated participation in the reaction by the solvent. With 3α-acetoxyandrost-5-en-17-one as substrate, a complete reversal in the product distribution was observed. 3β-Haloandrost-5-en-17-ones gave mainly products that reflected S_N1 substitution of the halide. 3β-Hydroxy- and 3β-trifluoroacetoxyandrost-5-en-17-ones were formed. 3β-Methoxyandrost-5-en-17-one afforded in nearly identical yields androst-4-ene-3,17-dione, 3β-methoxy-6β-hydroxyandrost-4-en-17-one, 3β-methoxy-6-chloromercuriandrost-5-en-17-one and 6β-hydroxyandrost-4-ene-3,17-dione while androst-5-en-17-one yielded 3β,6β-dihydroxyandrost-4-en-17-one, androst-5-ene-7,17-dione and androst-4-ene-3,17-dione. The effects of solvent and other mercury salts on the reaction were also studied. Treibs oxidation was successful in chloroform, carbon tetrachloride, and dibromomethane, but not in other solvents tested. 3β-Acetoxy-6-bromomercuriandrost-5-en-17-one was obtained in dibromomethane. Replacement of the reagent by mercury(II) trichloroacetate altered the intermediates formed but not the products. Mercury(II) tribromoacetate was unreactive, however. (*Steroids* **63**:650–664, 1998) *© 1998 by Elsevier Science Inc.*

Keywords: mercury(II) tribromoacetate; mercury(II) trichloroacetate; mercury(II) trifluoroacetate; Δ^5-steroid; Treibs

Introduction

The reaction of Δ^5-steroids (e.g., **1**) with mercury(II) trifluoroacetate was first reported by Massiot et al.[1] These olefins were converted to 6β-hydroxy-Δ^4-derivatives (e.g., **7**) (Treibs oxidation).[2] Later workers established that the 4β-proton was lost during the formation of the Δ^4 bond and proposed that the reaction proceeded via a mercurinium ion (**2**) and an allylic organomercurial (**5**).[3] Recently two side products from this reaction, **4a** and **8a**, were identified (Scheme 1).[4]

This facile oxidation of C-6 suggests potential applications in the synthesis of important steroid-based compounds (e.g., the ecdysones and the antibiotic viridin). In an effort to investigate the scope and limitations of this reaction, which has been the subject of very little research, the effect of steroid structure, in particular the variation of substituents at C-3, was explored.

Address reprint requests to Paul B. Reese, University of the West Indies, Chemistry Department, Mona, Kingston 7, Jamaica.
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The standard reaction protocol involved the addition of the substrates to a solution of mercuric oxide and trifluoroacetic anhydride in dichloromethane. This mixture was stirred at room temperature for 24 h and was treated with saturated sodium hydrogen carbonate solution during the work-up procedure. In this paper, the isolation of reaction intermediates and the effects of varying the solvent and mercury salt (with 3β-acetoxyandrost-5-en-17-one, **1a**, as substrate) are also discussed.

Experimental

Melting points were determined on a Thomas-Hoover melting-point apparatus using open-ended capillary tubes or on a Köfler hot stage instrument. Ultraviolet spectra were recorded on a Pye Unicam PU8800 spectrophotometer. Rotations were measured, unless otherwise stated, for solutions in chloroform with a Perkin Elmer 241 mc polarimeter. Infrared spectra were recorded on Perkin Elmer 1600 FT-IR and 735b spectrometers with KBr discs being the primary medium employed. Mass spectral data (high resolution electron impact ionization [EI] and chemical ionization [CI]) were determined at an ionizing voltage of 70 eV on Kratos A.E.I. MS-50 and MS-12 spectrometers, respectively. ^{1}H NMR

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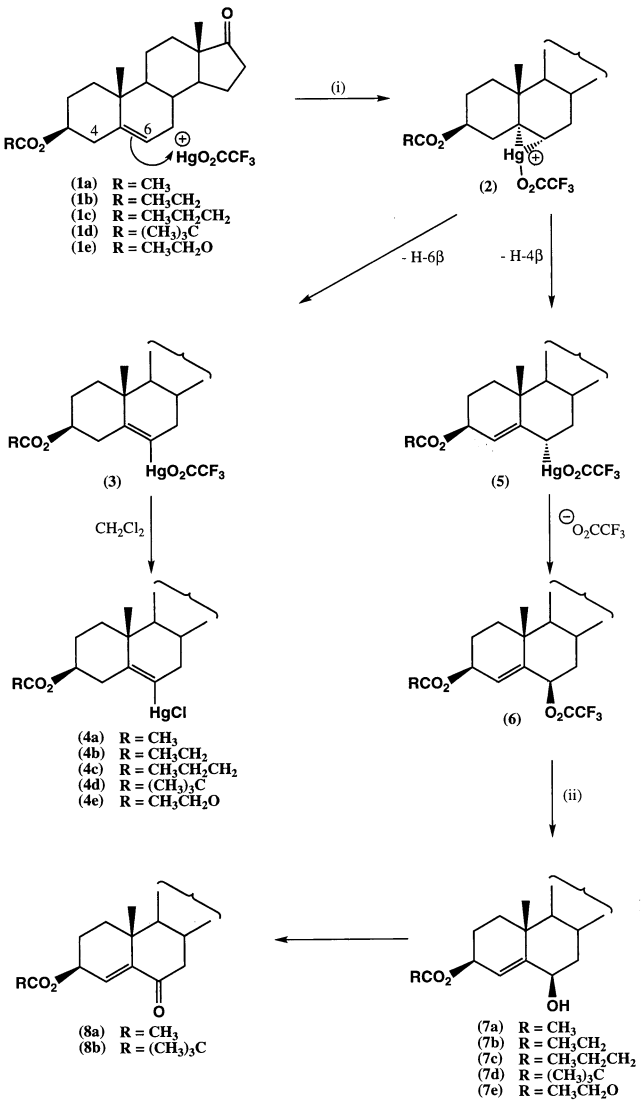


Scheme 1 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Cl_2$ (ii) aq. $NaHCO_3$.

spectra were recorded on Bruker AM 300 and AC 200 instruments operating at 300 MHz and 200 MHz, respectively, in the indicated solvent and were referenced to internal tetramethylsilane. ^{13}C NMR spectra were determined on the same instruments but at 75 MHz and 50 MHz, respectively. Petrol refers to the petroleum fraction of boiling range 60–80°C.

3β-Acetoxyandrost-5-en-17-one (**1a**),[5] 3β-carboethoxyandrost-5-en-17-one (**1e**),[6] 3β-bromoandrost-5-en-17-one (**27**),[7] 3β-chloroandrost-5-en-17-one (**28**),[8] 3β-methoxyandrost-5-en-17-one (**34**),[8] and androst-5-en-17-one (**37**)[9] were prepared by literature methods. The preparations reported below are of substrates that were either new or synthesized using adaptations of literature methods. All substrates gave satisfactory analytical and spectral data. All new compounds gave satisfactory NMR and mass spectral/combustion analysis data.

*3β-Propionoxyandrost-5-en-17-one (**1b**)*

Toluene-p-sulfonyl chloride (11.6 g, 60.4 mmol) was added to a solution of propionic acid (2.4 mL, 32 mmol) in dry pyridine (40 mL) and the mixture was stirred for 1 h. The solution was cooled in ice and 3β-hydroxyandrost-5-en-17-one (**17**) (2.00 g, 6.93 mmol) was added. The reaction mixture was allowed to attain room temperature overnight. Ethyl acetate was added and the diluted mixture was washed with cold, dilute hydrochloric acid. The organic solution was washed with water and saturated sodium hydrogen carbonate solution and was dried. Removal of the solvent in vacuo yielded 3β-propionoxyandrost-5-en-17-one (**1b**) (2.41 g, 6.70 mmol, 97%), which crystallized from ethyl acetate-petrol as prisms, m.p. 195–196°C, $[\alpha]_D$ − 4.26° (c = 0.09), lit.[10] 197–198°; IR ν_{max} 1739, 1183 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.05 (3H, s, H-19), 1.14 (3H, t, J = 8 Hz, CH_3CH_2), 2.33 (2H, q, J = 8 Hz, CH_3CH_2), 4.60 (1H, m, w/2 = 19 Hz, H-3α), 5.42 (1H, d, J = 4 Hz, H-6); ^{13}C NMR ($CDCl_3$) δ 9.1 ($\underline{C}H_3CH_2CO_2$), 13.4 (C-18), 19.2 (C-19), 20.2 (C-11), 21.7 (C-15), 27.6 ($CH_3\underline{C}H_2CO_2$), 27.7 (C-2), 30.6 (C-7), 31.3 (C-12), 31.3 (C-8), 35.7 (C-16), 36.6 (C-10), 36.8 (C-1), 38.0 (C-4), 47.4 (C-13), 50.0 (C-9), 51.6 (C-14), 73.3 (C-3), 121.7 (C-6), 139.8 (C-5), 173.8 ($CH_3CH_2\underline{C}O_2$), 220.9 (C-17).

*3β-Butyroxyandrost-5-en-17-one (**1c**)*

Toluene-p-sulfonyl chloride (9.0 g, 52.0 mmol) was added to a solution of butyric acid (10 mL, 110 mmol) in dry pyridine (60 mL). The reactants were stirred for 6 h then cooled in ice. 3β-Hydroxyandrost-5-en-17-one (**17**) (3.00 g, 10.4 mmol) was added and the mixture was stirred overnight. Ethyl acetate was added and the diluted reaction mixture was treated with excess dilute hydrochloric acid, water, and saturated sodium hydrogen carbonate solution. The organic solution was dried and the solvent was removed in vacuo to give 3β-butyroxyandrost-5-en-17-one (**1c**) (3.70 g, 10.3 mmol, 99%) as an off-white powder. Recrystallization from ethyl acetate yielded needles, m.p. 164.5–165°C, $[\alpha]_D$ 0° (c = 0.11), lit.[11] 168–169°C; IR ν_{max} 1730, 1190 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.95 (3H, s, H-18), 0.95 (3H, t, J = 7 Hz, $CH_3CH_2CH_2CO_2$), 1.06 (3H, s, H-19), 1.68 (2H, sex, J = 7 Hz, $CH_3C\underline{H}_2CH_2CO_2$), 2.27 (2H, t, J = 7 Hz, $CH_3CH_2C\underline{H}_2CO_2$), 4.63 (1H, m, w/2 = 22 Hz, H-3α), 5.42 (1H, d, J = 4 Hz, H-6); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18)*, 13.6 ($\underline{C}H_3CH_2CH_2CO_2$)*, 18.5 ($CH_3\underline{C}H_2CH_2CO_2$), 19.3 (C-19), 20.3 (C-11), 21.9 (C-15), 27.7 (C-2), 30.7 (C-7), 31.4 (C-12), 31.4 (C-8), 35.8 (C-16), 36.5 ($CH_3CH_2\underline{C}H_2CO_2$), 36.7 (C-10), 36.9 (C-1), 38.1 (C-4), 47.5 (C-13), 50.1 (C-9), 51.6 (C-14), 73.4 (C-3), 121.8 (C-6), 139.9 (C-5), 173.2 ($CH_3CH_2CH_2\underline{C}O_2$), 221.5 (C-17). (* = interchangeable assignments).

*3β-Pivaloxyandrost-5-en-17-one (**1d**)*

3β-Hydroxyandrost-5-en-17-one (**17**) (2.00 g, 6.93 mmol) was dissolved in pyridine (6 mL) and the solution was cooled in ice. Pivaloyl chloride (7 mL, 57 mmol) was added with stirring. The mixture was allowed to warm to room temperature and then was heated at 85°C for 14 h. Diethyl ether was added and the diluted reaction mixture was washed with saturated solutions of copper(II) sulfate and sodium chloride, and was dried. The solvent was evaporated in vacuo. Unreacted pivaloyl chloride was removed by heating the sample under reduced pressure at 100°C for 8 h to give 3β-pivaloxyandrost-5-en-17-one (**1d**) (2.36 g, 6.33 mmol, 91%), which crystallized from ethyl acetate as needles, m.p. 193.5–194.5°C, $[\alpha]_D$ 0.0° (c = 0.11); IR ν_{max} 1728, 1159 cm^{-1}; Combustion analysis: Found: C, 77.36%; H, 9.77%. ($C_{24}H_{36}O_3$ requires C, 77.36%; H, 9.75%); MS (CI NH_3) m/z (%) 390 (M^+, 6), 272 (20), 271 (100), 270 (38), 28 (10). ($C_{24}H_{36}O_3NH_4$ requires 390); ^1H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.06 (3H, s, H-19), 1.20 (9H, s, $(CH_3)_3CCO_2$), 4.58 (1H, m, w/2 = 22 Hz, H-3α), 5.41 (1H, d, J = 4 Hz, H-6); ^{13}C NMR ($CDCl_3$) δ 13.4 (C-18), 19.3 (C-19), 20.2 (C-11), 21.7 (C-15), 27.0 [$(\underline{C}H_3)_3CCO_2$], 27.5 (C-2), 30.7 (C-7), 31.3 (C-12), 31.3 (C-8), 35.7 (C-16), 36.6 (C-10), 36.8

(C-1), 37.8 (C-4), 38.5 [$(CH_3)_3\underline{C}CO_2$], 47.4 (C-13), 50.0 (C-9), 51.6 (C-14), 73.1 (C-3), 121.6 (C-6), 139.9 (C-5), 177.8 [$(CH_3)_3C\underline{C}O_2$], 220.9 (C-17).

3β-Formyloxyandrost-5-en-17-one (9)

3β-Hydroxyandrost-5-en-17-one (**17**) (3.00 g, 10.4 mmol) was dissolved in a 90% aqueous formic acid (30 mL, 708 mmol) and the solution was stirred for 19 h. Water (40 mL) was added and the precipitated steroid was filtered, washed with water, and redissolved in ethyl acetate. The organic solution was treated with saturated sodium bicarbonate solution and dried. The solvent was evaporated under reduced pressure to yield 3β-formyloxyandrost-5-en-17-one (**9**) (3.30 g, 10.4 mmol, 100%), which crystallized from ethyl acetate as needles, m.p. 144.5–145°C, $[\alpha]_D$ − 13° (c = 0.10), lit.[12] 147–148°C, $[\alpha]_D$ − 3.4°; IR ν_{max} 1730, 1700, 1370 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.07 (3H, s, H-19), 4.74 (1H, m, w/2 = 19 Hz, H-3α), 5.43 (1H, d, J = 4 Hz, H-6), 8.05 (1H, d, J = 0.5 Hz, CHO); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 19.3 (C-19), 20.3 (C-11), 21.9 (C-15), 27.6 (C-2), 30.7 (C-7), 31.3 (C-12), 31.4 (C-8), 35.8 (C-16), 36.7 (C-10), 36.8 (C-1), 38.0 (C-4), 47.5 (C-13), 50.0 (C-9), 51.6 (C-14), 73.6 (C-3), 122.2 (C-6), 139.5 (C-5), 160.6 (CHO), 221.2 (C-17).

3α-Acetoxyandrost-5-en-17-one (22)

A stirred solution of 3β-toluene-p-sulfonoxyandrost-5-en-17-one (1.50 g, 3.39 mmol) in butanone (7.5 mL) was treated with freshly recrystallized tetra-n-butylammonium acetate (6.0 g, 15 mmol). The reaction mixture was refluxed for 9 h. The solvent was removed under reduced pressure and the residue was chromatographed. Elution with 5% acetone in petrol gave 3α,5α-cycloandrost-6-en-17-one (40 mg, 0.15 mmol, 4.4%), which crystallized from acetone-petrol as needles, m.p. 138–140°C, $[\alpha]_D$ + 13° (c = 0.10), lit.[13] m.p. 137–138°C, $[\alpha]_D$ + 13°; IR ν_{max} 1731 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.48 (1H, d, J = 8 Hz, H-4β), 0.49 (1H, d, J = 8 Hz, H-4α), 0.94 (6H, s, H-18, H-19), 5.27 (1H, dd, J = 3, 10 Hz, H-7), 5.56 (1H, d, J = 10 Hz, H-6); ^{13}C NMR ($CDCl_3$) δ 13.9 (C-18), 14.7 (C-4), 17.8 (C-19), 21.5 (C-15), 21.8 (C-11), 25.0 (C-2), 25.8 (C-3), 31.5 (C-12), 31.8 (C-1), 35.9 (C-8), 35.9 (C-16), 36.7 (C-5), 42.7 (C-10), 46.3 (C-9), 48.5 (C-13), 50.1 (C-14), 124.8 (C-6), 132.9 (C-7), 220.9 (C-17).

Further elution afforded androsta-3,5-dien-17-one (388 mg, 1.44 mmol, 42%), which crystallized from ethyl acetate-petrol as amorphous crystals, m.p. 87–88°C, $[\alpha]_D$ − 30° (c = 0.1); lit.[14] m.p. 88–89°C, $[\alpha]_D$ − 30° (c = 2.04); UV (EtOH) λ_{max} 235 nm, log ε = 4.26; IR ν_{max} 1730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 0.98 (3H, s, H-19), 5.42 (1H, d, J = 3 Hz, H-6), 5.62 (1H, dd, J = 4, 16 Hz, H-3), 5.92 (1H, d, J = 16 Hz, H-4); ^{13}C NMR ($CDCl_3$) δ 13.6 (C-18), 18.7 (C-19), 20.2 (C-11), 21.8 (C-15), 22.9 (C-2), 30.6 (C-7), 31.4 (C-8), 31.4 (C-12), 33.6 (C-1), 35.2 (C-10), 35.8 (C-16), 47.7 (C-13), 48.4 (C-9), 51.9 (C-14), 122.1 (C-6), 125.3 (C-4), 128.7 (C-3), 141.5 (C-5), 221.1 (C-17).

Elution with 10% acetone in petrol gave a mixture that was rechromatographed on a 5% silver nitrate-silica gel column. Elution with dichloromethane gave 6β-acetoxy-3α,5α-cycloandrostan-17-one (191 mg, 0.58 mmol, 17%), which crystallized from methanol as prisms, m.p. 105–109°C, $[\alpha]_D$ + 118° (c = 0.10), lit.[7] m.p. 113–114°C, $[\alpha]_D$ + 117°; IR ν_{max} 1733, 1243 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.50 (2H, m, w/2 = 16 Hz, H-4β, 4α), 0.95 (3H, s, H-18), 1.06 (3H, s, H-19), 2.10 (3H, s, CH_3CO_2), 4.55 (1H, t, J = 3 Hz, H-6α); ^{13}C NMR ($CDCl_3$) δ 12.2 (C-4), 13.9 (C-18), 19.3 (C-19), 21.5 ($\underline{C}H_3CO_2$), 21.7 (C-15), 21.9 (C-11), 24.2 (C-3), 24.9 (C-2), 30.3 (C-8), 31.7 (C-12), 33.1 (C-7), 34.2 (C-1), 35.8 (C-16), 36.3 (C-5), 43.1 (C-10), 47.7 (C-9), 47.9 (C-13), 51.3 (C-14), 75.7 (C-6), 170.8 ($CH_3\underline{C}O_2$), 220.9 (C-17).

Further elution from the silver nitrate-silica gel column provided 3α-acetoxyandrost-5-en-17-one (**22**) (674 mg, 1.132 mmol, 33%), which crystallized from ethyl acetate-petrol as needles, m.p. 169.5–172°C $[\alpha]_D$ + 38° (c = 0.09), lit.[15] m.p. 165–166°C, $[\alpha]_D$ + 34° (c = 0.3); IR ν_{max} 1736, 1725, 1238 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.91 (3H, s, H-18), 1.05 (3H, s, H-19), 2.03 (3H, s, CH_3CO_2), 5.00 (1H, t, J = 3 Hz, H-3β), 5.32 (1H, dd, J = 2, 5 Hz, H-6); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 18.9 (C-19), 20.0 (C-11), 21.4 ($\underline{C}H_3CO_2$), 21.6 (C-15), 26.1 (C-2), 30.7 (C-7), 31.4 (C-8), 31.4 (C-12), 33.4 (C-1), 35.8 (C-16), 36.2 (C-4), 37.1 (C-10), 47.5 (C-13), 50.0 (C-9), 51.8 (C-14), 70.4 (C-3), 121.3 (C-6), 138.7 (C-5), 170.8 ($CH_3\underline{C}O_2$), 221.2 (C-17).

Treibs oxidation of 3β-acetoxyandrost-5-en-17-one (1a)

Trifluoroacetic anhydride (14 mL, 98 mmol) was added with stirring to a suspension of mercury(II) oxide (16.4 g, 75.7 mmol) in dichloromethane (1.0 L). The reactants were stirred until the metal oxide had dissolved. 3β-Acetoxyandrost-5-en-17-one (**1a**) (10.0 g, 30.3 mmol) was introduced into the pale yellow solution of mercury(II) trifluoroacetate. Off-white deposits of mercury(I) trifluoroacetate started appearing 3 min after the addition of the steroid. The reaction mixture was stirred for 24 h and was filtered through celite. The filtrate was washed with saturated sodium hydrogen carbonate solution and dried. Removal of the solvent in vacuo gave a brown foam (12.0 g), which was chromatographed. Elution with 15% ethyl acetate in petrol yielded 3β-acetoxy-6-chloromercuriandrost-5-en-17-one (**4a**)[4] (1.10 g, 1.95 mmol, 6.4%), which crystallized from ethyl acetate-petrol as needles, m.p. 210–215°C (dec.), $[\alpha]_D$ + 26° (c = 0.11); IR ν_{max} 1738, 1725, 1245 cm^{-1}; MS (CI NH_3) m/z (%) 587 (6), 586 (53), 585 (33), 584 (M^+, 100), 583 (61), 582 (73), 581 (45), 580 (25), 269 (71). ($C_{21}H_{29}{}^{35}Cl^{202}HgO_3NH_4$ requires 584); MS (EI) m/z (%) 506.1280 (5), 269.1907 (100), 105.0709 (16), 93.0705 (16), 81.0721 (46). ($C_{21}H_{29}{}^{35}Cl^{202}HgO_3$ − CH_3CO_2H requires 506.1300); ^1H NMR ($CDCl_3$) δ 0.88 (3H, s, H-18), 1.14 (3H, s, H-19), 2.05 (3H, s, CH_3CO_2), 4.65 (1H, m, w/2 = 21 Hz, H-3α); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 20.1 (C-19), 20.3 (C-11), 21.3 ($\underline{C}H_3CO_2$), 21.8 (C-15), 27.6 (C-2), 31.3 (C-12), 33.2 (C-8), 35.8 (C-16), 36.9 (C-1), 40.3 (C-10), 40.8 (C-7), 44.4 (C-4), 47.5 (C-13), 49.6 (C-9), 51.5 (C-14), 72.6 (C-3), 146.3 (C-6),* 146.5 (C-5),* 170.3 (CH_3CO_2), 220.2 (C-17). (* = interchangeable assignments).

Further elution gave 3β-acetoxyandrost-4-ene-6,17-dione (**8a**) (150 mg, 0.435 mmol, 1.4%), which crystallized from ethyl acetate as prisms, m.p. 209–212°C, $[\alpha]_D$ + 16° (c = 0.10), lit.[16] m.p. 216–218°C, $[\alpha]_D$ 0°; UV (EtOH) λ_{max} 232 nm, log ε = 3.93; IR ν_{max} 1734, 1693, 1238 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.93 (3H, s, H-18), 1.07 (3H, s, H-19), 2.09 (3H, s, CH_3CO_2), 5.35 (1H, dt, J = 3, 8 Hz, H-3α), 6.13 (1H, t, J = 2 Hz, H-4); ^{13}C NMR ($CDCl_3$) δ 13.7 (C-18), 19.6 (C-19), 20.0 (C-11), 21.1 ($\underline{C}H_3CO_2$), 21.5 (C-15), 24.0 (C-2), 31.0 (C-12), 33.7 (C-8), 34.4 (C-1), 35.6 (C-16), 38.2 (C-10), 44.9 (C-7), 47.7 (C-13), 51.1 (C-14), 51.5 (C-9), 69.1 (C-3), 129.4 (C-4), 147.4 (C-5), 170.7 ($CH_3\underline{C}O_2$), 201.3 (C-6), 219.7 (C-17).

Elution with 20% ethyl acetate in petrol afforded 3β-acetoxy-6β-hydroxyandrost-4-en-17-one (**7a**) (4.51 g, 13.0 mmol, 43%), which crystallized from ethyl acetate-petrol as amorphous crystals, m.p. 179–182°C, $[\alpha]_D$ + 29° (c = 0.11), lit.[1] m.p. 148–150°C, $[\alpha]_D$ + 25° (c = 1.1); IR ν_{max} 3382, 1727, 1238 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.92 (3H, s, H-18), 1.32 (3H, s, H-19), 2.06 (3H, s, CH_3CO_2), 4.28 (1H, t, J = 4 Hz, H-6α), 5.23 (1H, dt, J = 3, 8 Hz, H-3α), 5.50 (1H, s, H-4); ^{13}C NMR ($CDCl_3$) δ 13.7 (C-18), 20.0 (C-11), 21.2 (C-19), 21.2 ($\underline{C}H_3CO_2$), 21.6 (C-15), 24.7 (C-2), 29.7 (C-8), 31.2 (C-12), 35.6 (C-16), 36.4 (C-1), 36.7 (C-10), 37.7

(C-7), 47.6 (C-13), 50.9 (C-14), 54.0 (C-9), 70.4 (C-3), 73.4 (C-6), 124.7 (C-4), 148.6 (C-5), 170.7 ($CH_3\underline{C}O_2$), 220.7 (C-17).

*Treibs oxidation of 3β-propionoxyandrost-5-en-17-one (**1b**)*

Mercury(II) oxide (3.30 g, 15.23 mmol) and trifluoroacetic anhydride (2.7 mL, 19.4 mmol) were stirred together in dichloromethane (210 mL). 3β-Propionoxyandrost-5-en-17-one (**1b**) (2.10 g, 6.10 mmol) was added and the solution was stirred for 24 h. The reaction mixture was filtered through celite, and the filtrate was washed with saturated sodium hydrogen carbonate solution and dried. Removal of solvent under reduced pressure yielded a brown foam (2.80 g), which was chromatographed. Elution with 25% ethyl acetate in petrol gave unreacted starting material (33 mg, 0.096 mmol, 1.6%), then 6-chloromercuri-3β-propionoxyandrost-5-en-17-one (**4b**) (104 mg, 0.179 mmol, 2.9%), which crystallized from ethyl acetate as rectangular prisms, m.p. 228–234°C, $[\alpha]_D$ − 38° (c = 0.11); IR ν_{max} 1730, 1200 cm^{-1}; Combustion analysis: Found: C, 46.06%; H, 5.43%. ($C_{22}H_{31}ClHgO_3$ requires C, 45.60%; H, 5.39%); MS (CI NH_3) m/z (%) 600 (21), 599 (12), 598 (M^+, 37), 597 (23), 596 (25), 595 (17), 594 (10), 362 (71), 271 (92), 270 (95), 269 (40), 35 (100). ($C_{22}H_{31}{}^{35}Cl^{202}HgO_3NH_4$ requires 598); ^{1}H NMR ($CDCl_3$) δ 0.88 (3H, s, H-18), 1.12 (3H, s, H-19), 1.12 (3H, t, J = 7.5 Hz, $CH_3CH_2CO_2$), 2.34 (2H, q, J = 7.5 Hz, $CH_3CH_2CO_2$), 4.66 (1H, m, w/2 = 24 Hz, H-3α); ^{13}C NMR ($CDCl_3$) δ 9.0 ($\underline{C}H_3CH_2CO_2$), 13.4 (C-18), 19.9 (C-19), 20.1 (C-11), 21.6 (C-15), 27.4 (C-2), 27.7 ($CH_3\underline{C}H_2CO_2$), 31.0 (C-12), 33.0 (C-8), 35.6 (C-16), 36.7 (C-1), 40.1 (C-10), 40.5 (C-7), 44.2 (C-4), 47.4 (C-13), 49.4 (C-9), 51.3 (C-14), 72.5 (C-3), 146.0 (C-5), 146.2 (C-6), 173.6 ($CH_3CH_2\underline{C}O_2$), 220.4 (C-17).

Further elution produced 6β-hydroxy-3β-propionoxyandrost-4-en-17-one (**7b**) (625 mg, 1.73 mmol, 28%), which crystallized from ethyl acetate-petrol as cuboids, m.p. 139–140°C, $[\alpha]_D$ + 20° (c = 0.10); IR ν_{max} 3400, 1720 cm^{-1}; Combustion analysis: Found: C, 73.40%; H, 8.95%. ($C_{22}H_{32}O_4$ requires C, 73.29%; 8.95%); MS (CI NH_3) m/z (%) 378 (M^+, 57), 343 (40), 287 (57), 286 (100), 269 (14). ($C_{22}H_{32}O_4NH_4$ requires 378); ^{1}H NMR ($CDCl_3$) δ 0.88 (3H, s, H-18), 1.11 (3H, t, J = 7.5 Hz, $CH_3CH_2CO_2$), 1.28 (3H, s, H-19), 2.26 (2H, q, J = 7.5 Hz, $CH_3CH_2CO_2$), 3.25 (1H, b s, HO), 4.24 (1H, b s, H-6α), 5.21 (1H, t, J = 7 Hz, H-3α), 5.48 (1H, s, H-4); ^{13}C NMR ($CDCl_3$) δ 8.6 ($\underline{C}H_3CH_2CO_2$), 13.2 (C-18), 19.6 (C-11), 20.7 (C-19), 21.2 (C-15), 24.3 (C-2), 27.2 ($CH_3\underline{C}H_2CO_2$), 29.3 (C-8), 30.8 (C-12), 35.2 (C-16), 36.0 (C-1), 36.2 (C-10), 37.4 (C-7), 47.1 (C-13), 50.4 (C-14), 53.6 (C-9), 69.9 (C-3), 72.6 (C-6), 124.0 (C-4), 148.0 (C-5), 173.7 ($CH_3CH_2\underline{C}O_2$), 220.5 (C-17).

*Treibs oxidation of 3β-butyroxyandrost-5-en-17-one (**1c**)*

A solution of mercury(II) trifluoroacetate was prepared by stirring mercury(II) oxide (3.02 g, 14.0 mmol) with trifluoroacetic anhydride (2.4 mL, 17.2 mmol) in dichloromethane (200 mL). 3β-Butyroxyandrost-5-en-17-one (**1c**) (2.00 g, 5.58 mmol) was added and the mixture was stirred for 24 h and was filtered through celite to remove the mercurous deposits. The pale-yellow filtrate was washed with saturated sodium hydrogen carbonate solution. The organic solution was dried and the solvent was removed under reduced pressure to produce a yellow foam (2.44 g). Chromatography (10% ethyl acetate in petrol) gave unreacted starting material (24 mg, 0.067 mmol, 1.2%). Elution with 15% ethyl acetate in petrol afforded 3β-butyroxy-6-chloromercuriandrost-5-en-17-one (**4c**) (95 mg, 0.160 mmol, 2.9%), which crystallized from ethyl acetate-petrol as fine, wispy needles, m.p. 197–198°C, $[\alpha]_D$ − 16° (c = 0.13); IR ν_{max} 1730, 1715, 1260 cm^{-1}; Combustion analysis: Found: C, 46.81%; H, 5.66%. ($C_{23}H_{33}ClHgO_3$ requires C, 46.45%; H, 5.60%); MS (CI NH_3) m/z (%) 614 (46), 613 (37), 612 (M^+, 100), 611 (59), 610 (79), 609 (45), 270 (37), 269 (56). ($C_{23}H_{33}{}^{35}Cl^{202}HgO_3NH_4$ requires 612); ^{1}H NMR ($CDCl_3$) δ 0.89 (3H, s, H-18), 0.97 (3H, t, J = 7 Hz, $CH_3CH_2CH_2CO_2$), 1.14 (3H, s, H-19), 1.66 (2H, sex, J = 7 Hz, $CH_3C\underline{H}_2CH_2CO_2$), 2.29 (2H, t, J = 7 Hz, $CH_3CH_2C\underline{H}_2CO_2$), 4.67 (1H, m, w/2 = 20 Hz, H-3α); ^{13}C NMR ($CDCl_3$) 13.5 (C-18),* 13.6 ($\underline{C}H_3CH_2CH_2CO_2$),* 18.3 ($CH_3\underline{C}H_2CH_2CO_2$), 20.0 (C-19), 20.2 (C-11), 21.7 (C-15), 27.5 (C-2), 31.1 (C-12), 33.1 (C-8), 35.7 (C-16), 36.4 ($CH_3CH_2\underline{C}H_2CO_2$), 36.8 (C-1), 40.2 (C-10), 40.7 (C-7), 44.3 (C-4), 47.4 (C-13), 49.4 (C-9), 51.4 (C-14), 72.4 (C-3), 146.2 (C-6), 146.3 (C-5), 173.0 ($CH_3CH_2CH_2\underline{C}O_2$), 220.6 (C-17). (* = interchangeable assignments).

Further elution with 40% ethyl acetate in petrol produced 3β-butyroxy-6β-hydroxyandrost-4-en-17-one (**7c**) (827 mg, 2.21 mmol, 40%), which crystallized from ethyl acetate-petrol as large needles, m.p. 109–110°C, $[\alpha]_D$ + 24° (c = 0.10); IR ν_{max} 3525, 1730, 1190 cm^{-1}; MS (EI) m/z (%) 374.2542 (M^+, 1), 356.2348 (5), 286.1930 (100), 271.1697 (22), 93.0703 (12), 91.0546 (18), 79.0545 (10), 71.0496 (14). ($C_{23}H_{34}O_4$ requires 374.2457); ^{1}H NMR ($CDCl_3$) δ 0.93 (3H, s, H-18), 0.97 (3H, t, J = 7 Hz, $CH_3CH_2CH_2CO_2$), 1.30 (3H, s, H-19), 1.68 (2H, sex, J = 7 Hz, $CH_3C\underline{H}_2CH_2CO_2$), 2.31 (2H, t, J = 7 Hz, $CH_3CH_2C\underline{H}_2CO_2$), 4.29 (1H, t, J = 3 Hz, H-6α), 5.25 (1H, dt, J = 2, 8 Hz, H-3α), 5.50 (1H, d, J = 1 Hz, H-4); ^{13}C NMR ($CDCl_3$) δ 13.7 ($\underline{C}H_3CH_2CH_2CO_2$),* 13.8 (C-18),* 18.5 ($CH_3\underline{C}H_2CH_2CO_2$), 20.1 (C-11), 21.3 (C-19), 21.7 (C-15), 24.9 (C-2), 29.9 (C-8), 31.4 (C-12), 35.8 (C-16), 36.5 (C-1), 36.5 ($CH_3CH_2\underline{C}H_2CO_2$), 36.8 (C-10), 37.8 (C-7), 47.7 (C-13), 51.0 (C-14), 54.2 (C-9), 70.3 (C-3), 73.6 (C-6), 125.1 (C-4), 148.6 (C-5), 173.5 ($CH_3CH_2CH_2\underline{C}O_2$), 221.0 (C-17). (* = interchangeable assignments).

*Treibs oxidation of 3β-pivaloxyandrost-5-en-17-one (**1d**)*

Mercury(II) oxide (1.45 g, 6.71 mmol) and trifluoroacetic anhydride (1.1 mL, 7.8 mmol) were stirred together in dichloromethane (100 mL). 3β-Pivaloxyandrost-5-en-17-one (**1d**) (1.0 g, 2.7 mmol) was added and the solution was stirred for 24 h. The reaction mixture was filtered through celite to remove the mercurous deposits and the filtrate was washed with saturated sodium hydrogen carbonate solution and dried. Evaporation of the solvent under reduced pressure left a light-brown foam (1.3 g). Chromatography (35% ethyl acetate in petrol) yielded 6-chloromercuri-3β-pivaloxyandrost-5-en-17-one (**4d**) (36 mg, 0.059 mmol, 2.2%), which crystallized from ethyl acetate-petrol as small needles, m.p. 240°C, $[\alpha]_D$ − 15° (c = 0.11); IR ν_{max} 1738, 1722, 1163 cm^{-1}; Combustion analysis: Found: C, 47.64%; H, 5.92%. ($C_{24}H_{35}ClHgO_3$ requires C, 47.44%; H, 5.81%); MS (CI NH_3) m/z (%) 628 (30), 627 (18), 626 (M^+, 53), 625 (35), 624 (37), 623 (23), 622 (14), 271 (24), 270 (29), 269 (100). ($C_{24}H_{35}{}^{35}Cl^{202}HgO_3NH_4$ requires 626); ^{1}H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.14 (3H, s, H-19), 1.19 (9H, s, $(CH_3)_3CCO_2$), 4.63 (1H, m, w/2 = 22 Hz, 3-Hα); ^{13}C NMR ($CDCl_3$) δ 13.4 (C-18), 20.0 (C-19), 20.2 (C-11), 21.6 (C-15), 27.0 [$(\underline{C}H_3)_3CCO_2$], 27.3 (C-2), 31.1 (C-12), 33.0 (C-8), 35.7 (C-16), 36.7 (C-1), 38.5 [$(CH_3)_3\underline{C}CO_2$], 40.2 (C-10), 40.6 (C-7), 44.1 (C-4), 47.4 (C-13), 49.4 (C-9), 51.3 (C-14), 72.3 (C-3), 146.1 (C-5), 146.1 (C-6), 177.7 [$(CH_3)_3C\underline{C}O_2$], 220.3 (C-17).

Further elution produced 3β-pivaloxyandrost-4-ene-6,17-dione (**8b**) (61 mg, 0.157 mmol, 5.8%) which crystallized from ethyl acetate-petrol as needles, m.p. 221–222°C, $[\alpha]_D$ + 15° (c = 0.09); UV (EtOH) λ_{max} 234 nm, log ε = 3.97; IR ν_{max} 1729, 1690, 1154 cm^{-1}; Combustion analysis: Found: C, 74.53%; H, 8.71%. ($C_{24}H_{34}O_4$ requires C, 74.56%; H, 8.87%); MS (CI NH_3) m/z (%)

405 (35), 404 (M^+, 100), 302 (43), 285 (49). ($C_{24}H_{34}O_4NH_4$ requires 404); ^{1}H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.10 (3H, s, H-19), 1.20 (9H, s, $(CH_3)_3CCO_2$), 5.30 (1H, dt, J = 2, 8 Hz, H-3α), 6.10 (1H, t, J = 1 Hz, H-4); ^{13}C NMR ($CDCl_3$) δ 13.7 (C-18), 19.7 (C-19), 20.0 (C-11), 21.5 (C-15), 24.0 (C-2), 27.1 [($\underline{C}H_3)_3CCO_2$], 30.9 (C-12), 33.6 (C-8), 34.4 (C-1), 35.6 (C-16), 38.2 (C-10), 38.7 [$(CH_3)_3\underline{C}CCO_2$], 44.9 (C-7), 47.6 (C-13), 51.1 (C-14), 51.5 (C-9), 68.9 (C-3), 129.8 (C-4), 147.2 (C-5), 178.1 [$(CH_3)_3C\underline{C}O_2$], 201.3 (C-6), 219.7 (C-17).

Further elution yielded 6β-hydroxy-3β-pivaloxyandrost-4-en-17-one (405 mg, 1.04 mmol, 34%) (**7d**), which crystallized from ethyl acetate as needles, m.p. 174–176°C, $[\alpha]_D$ + 27° (c = 0.10); IR ν_{max} 3475, 1724, 1153 cm^{-1}; Combustion analysis: Found: C, 74.17%; H, 9.38%. ($C_{24}H_{36}O_4$ requires C, 74.18%; H, 9.34%); MS (CI NH_3) m/z (%) 406 (M^+, 92), 371 (100), 370 (42), 287 (67), 286 (87), 269 (22), 57 (37). ($C_{24}H_{36}O_4NH_4$ requires 406); ^{1}H NMR ($CDCl_3$) δ 0.94 (3H, s, H-18), 1.20 (9H, s, $(CH_3)_3CCO_2$), 1.33 (3H, s, H-19), 4.29 (1H, t, J = 3 Hz, H-6α), 5.20 (1H, dt, J = 2, 8 Hz, H-3α), 5.50 (1H, s, H-4); ^{13}C NMR ($CDCl_3$) δ 13.6 (C-18), 19.9 (C-11), 21.1 (C-19), 21.5 (C-15), 24.5 (C-2), 27.0 [($\underline{C}H_3)_3CCO_2$], 29.7 (C-8), 31.2 (C-12), 35.6 (C-16), 36.4 (C-1), 36.6 (C-10), 37.8 (C-7), 38.4 [$(CH_3)_3\underline{C}CO_2$], 47.5 (C-13), 50.8 (C-14), 54.0 (C-9), 70.0 (C-3), 73.3 (C-6), 124.9 (C-4), 148.0 (C-5), 178.1 [$(CH_3)_3C\underline{C}O_2$], 220.7 (C-17).

*Treibs oxidation of 3β-carboethoxyandrost-5-en-17-one (**1e**)*

Mercury(II) oxide (3.0 g, 13.87 mmol) and trifluoroacetic anhydride (2.4 mL, 16.9 mmol) were stirred together in dichloromethane (200 mL). 3β-Carboethoxyandrost-5-en-17-one (**1e**) (2.00 g, 5.55 mmol) was added and the solution was stirred for 24 h. The reaction mixture was filtered through celite to remove the off-white mercury(I) deposits. The lime green filtrate was washed with saturated sodium hydrogen carbonate solution and dried. Evaporation of the solvent under reduced pressure gave a brown foam (2.5 g), which was chromatographed. Elution with 10% ethyl acetate in petrol afforded unreacted starting material (99 mg, 0.275 mmol, 5.0%). Further elution (15% ethyl acetate in petrol) gave 3β-carboethoxy-6-chloromercuriandrost-5-en-17-one (**4e**) (213 mg, 0.358 mmol, 6.5%), which crystallized from methanol as rectangular prisms, m.p. 210–211°C, $[\alpha]_D$ − 26° (c = 0.10); IR ν_{max} 1737, 1254 cm^{-1}; Combustion analysis: Found: C, 44.48%; H, 5.37%. ($C_{22}H_{31}ClHgO_4$ requires C, 44.37%; H, 5.25%); MS (CI NH_3) m/z (%) 616 (1), 615 (1), 614 (M^+, 2), 613 (1), 612 (2), 611 (2), 269 (6), 157 (57), 96 (52), 79 (100). ($C_{22}H_{31}{}^{35}Cl^{202}HgO_4NH_4$ requires 614); ^{1}H NMR ($CDCl_3$) δ 0.88 (3H, s, H-18), 1.13 (3H, s, H-19), 1.33 (3H, t, J = 7.5 Hz, $CH_3CH_2OCO_2$), 4.20 (2H, q, J = 7.5 Hz, $CH_3CH_2OCO_2$), 4.54 (1H, m, w/2 = 22 Hz, H-3α); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 14.2 ($\underline{C}H_3CH_2OCO_2$), 20.0 (C-19), 20.2 (C-11), 21.8 (C-15), 27.3 (C-2), 31.2 (C-12), 32.7 (C-8), 35.7 (C-16), 36.8 (C-1), 40.0 (C-7), 40.0 (C-10), 43.7 (C-4), 47.4 (C-13), 49.6 (C-9), 51.4 (C-14), 63.8 ($CH_3\underline{C}H_2OCO_2$), 76.5 (C-3), 147.4 (C-5),* 147.7 (C-6),* 154.2 ($CH_3CH_2O\underline{C}O_2$), 220.6 (C-17). (* = interchangeable assignments).

Elution with 30% ethyl acetate in petrol yielded 3β-carboethoxy-6β-hydroxyandrost-4-en-17-one (**7e**) (409 mg, 1.09 mmol, 20%), which crystallized from ethyl acetate as rectangular prisms, m.p. 183.5–184.5°C, $[\alpha]_D$ + 35° (c = 0.07); IR ν_{max} 3469, 1747, 1725, 1259 cm^{-1}; Combustion analysis: Found: C, 70.07%; H, 8.81%. ($C_{22}H_{32}O_5$ requires C, 70.17%; H, 8.57%); MS (CI NH_3) m/z (%) 394 (M^+, 78), 358 (39), 287 (58), 286 (100). ($C_{22}H_{32}O_5NH_4$ requires 394); ^{1}H NMR ($CDCl_3$) δ 0.92 (3H, s, H-18), 1.29 (3H, s, H-19), 1.30 (3H, t, J = 7.5 Hz, $CH_3CH_2OCO_2$), 2.65 (1H, b s, HO), 4.20 (2H, q, J = 7.5 Hz, $CH_3CH_2OCO_2$), 4.26 (1H, b s, H-6α), 5.10 (1H, t, J = 8 Hz, H-3α), 5.56 (1H, s, H-4); ^{13}C NMR ($CDCl_3$) δ 13.4 (C-18), 13.9 ($\underline{C}H_3CH_2OCO_2$), 19.7 (C-11), 20.8 (C-19), 21.4 (C-15), 24.4 (C-2), 29.5 (C-8), 31.0 (C-12), 35.4 (C-16), 36.0 (C-1), 36.5 (C-10), 37.4 (C-7), 47.3 (C-13), 50.6 (C-14), 53.8 (C-9), 63.5 ($CH_3\underline{C}H_2OCO_2$), 72.8 (C-3), 73.7 (C-6), 123.6 (C-4), 148.8 (C-5), 154.5 ($CH_3CH_2O\underline{C}O_2$), 220.7 (C-17).

*Treibs oxidation of 3β-formyloxyandrost-5-en-17-one (**9**)*

Mercury(II) oxide (3.42 g, 15.8 mmol) was stirred with trifluoroacetic anhydride (2.7 mL, 19.5 mmol) in dichloromethane. 3β-Formyloxyandrost-5-en-17-one (**9**) (2.00 g, 6.32 mmol) was introduced after the metal oxide had dissolved. The reaction mixture was stirred for 24 h and filtered through celite to remove the mercurous deposits. The filtrate was washed with saturated sodium bicarbonate solution and was dried. The solvent was evaporated in vacuo and the resultant yellow-brown foam (2.24 g) was chromatographed. Elution with 20% ethyl acetate in petrol gave unreacted starting material (124 mg, 0.391 mmol, 6.2%) and later afforded 3β,6β-diformyloxyandrost-4-en-17-one (**12**) (50 mg, 0.139 mmol, 2.2%), which crystallized from ethyl acetate-petrol as needles, m.p. 154–155°C, $[\alpha]_D$ + 60° (c = 0.10); IR ν_{max} 1720, 1700, 1190 cm^{-1}; Combustion analysis: Found: C, 69.59%; H, 7.86%. ($C_{21}H_{28}O_5$ requires C, 69.96%; H, 7.83%); MS (CI NH_3) m/z (%) 378 (M^+, 51), 315 (100), 314 (55), 269 (86). ($C_{21}H_{28}O_5NH_4$ requires 378); ^{1}H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.21 (3H, s, H-19), 5.40 (1H, t, J = 7 Hz, H-3α), 5.46 (1H, s, H-6α), 5.68 (1H, s, H-4), 8.06 (2H, s, CHO-3β, 6β); ^{13}C NMR ($CDCl_3$) δ 13.8 (C-18), 20.0 (C-11), 20.5 (C-19), 21.7 (C-15), 24.6 (C-2), 30.4 (C-8), 31.2 (C-12), 35.7 (C-16), 35.9 (C-7), 36.3 (C-1), 36.8 (C-10), 47.6 (C-13), 50.8 (C-14), 53.7 (C-9), 69.8 (C-3), 74.6 (C-6), 127.9 (C-4), 143.8 (C-5), 160.1 (CHO-6β),* 160.7 (CHO-3β),* 220.3 (C-17). (* = interchangeable assignments).

Further elution produced androst-4-ene-3,17-dione (**15**) (20 mg, 0.070 mmol, 1.1%), which was recrystallized from acetone to give cuboids, m.p. 166–167°C, $[\alpha]_D$ + 197° (c = 0.10), lit.[17] m.p. 169–170°C, $[\alpha]_D$ + 205° (c = 0.10); UV (EtOH) λ_{max} 235 nm, log ε = 4.15; IR ν_{max} 1738, 1661 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.98 (3H, s, H-18), 1.28 (3H, s, H-19), 5.75 (1H, s, H-4); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 17.2 (C-19), 20.1 (C-11), 21.6 (C-15), 30.6 (C-12), 31.1 (C-7), 32.4 (C-6), 33.7 (C-2), 35.0 (C-8), 35.5 (C-1),* 35.6 (C-16),* 38.5 (C-10), 47.3 (C-13), 50.7 (C-14), 53.6 (C-9), 123.9 (C-4), 170.3 (C-5), 199.2 (C-3), 220.3 (C-17). (* = interchangeable assignments).

Elution with 30% ethyl acetate in petrol gave 3β-formyloxy-6β-hydroxyandrost-4-en-17-one (**10**) (328 mg, 0.987 mmol, 16%), which crystallized from ethyl acetate-petrol as small cuboids, m.p. 152–154°C, $[\alpha]_D$ + 33° (c = 0.11); IR ν_{max} 3375, 1725, 1715, 1170 cm^{-1}; MS (EI), m/z (%) 332.1983 (1), 314.1879 (5), 286.1932 (100), 271.1698 (53), 93.0705 (23), 91.0548 (22). ($C_{20}H_{28}O_4$ requires 332.1988); ^{1}H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.30 (3H, s, H-19), 4.26 (1H, s, H-6α), 5.36 (1H, t, J = 9 Hz, H-3α), 5.50 (1H, s, H-4), 8.09 (1H, s, CHO); ^{13}C NMR ($CDCl_3$) δ 13.8 (C-18), 20.1 (C-11), 21.3 (C-19), 21.7 (C-15), 24.8 (C-2), 29.8 (C-8), 31.3 (C-12), 35.8 (C-16), 36.4 (C-1), 36.8 (C-10), 37.7 (C-7), 47.7 (C-13), 51.1 (C-14), 54.1 (C-9), 70.3 (C-3), 73.5 (C-6), 124.3 (C-4), 149.4 (C-5), 160.8 (CHO), 220.8 (C-17). The isomeric but slightly more polar 6β-formyloxy-3β-hydroxyandrost-4-en-17-one (**13**) (37 mg, 0.111 mmol, 1.8%) was also obtained and crystallized from ethyl acetate as wispy needles, m.p. 194–196°C, $[\alpha]_D$ + 119° (c = 0.07); IR ν_{max} 3500, 1730, 1200 cm^{-1}; MS (CI NH_3) m/z (%) 350 (M^+, 100), 315 (24), 286 (29), 269 (26), ($C_{20}H_{28}O_4NH_4$ requires 350); MS (EI) m/z (%) 286.1933 (100), 271.1698 (16), 177.1279 (13), 105.0705 (14), 91.0548 (18), 79.0547 (15). ($C_{20}H_{28}O_4$ − HCO_2H requires

286.1933); ^{1}H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.20 (3H, s, H-19), 4.17 (1H, w/2 = 18 Hz, H-3α), 5.46 (1H, s, H-6α), 5.76 (1H, s, H-4), 8.08 (1H, s, CHO); ^{13}C NMR ($CDCl_3$) δ 13.7 (C-18), 20.0 (C-11), 20.6 (C-19), 21.7 (C-15), 28.8 (C-2), 30.5 (C-8), 31.3 (C-12), 35.7 (C-16), 36.0 (C-7), 36.7 (C-1), 36.8 (C-10), 47.6 (C-13), 50.9 (C-14), 53.8 (C-9), 67.6 (C-3), 75.2 (C-6), 132.8 (C-4), 141.4 (C-5), 160.4 (CHO), 220.5 (C-17).

Elution with 75% ethyl acetate in petrol gave 3β,4β-dihydroxyandrost-5-en-17-one (**14**) (29 mg, 0.095 mmol, 1.5%), which crystallized from ethyl acetate as amorphous crystals, m.p. 193–195°C, $[\alpha]_D$ − 14° (c = 0.09), lit.[18] m.p. 204–205°C, $[\alpha]_D$ − 29° (c = 0.23); IR ν_{max} 3320, 1740 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.21 (3H, s, H-19), 3.58 (1H, m w/2 = 19 Hz, H-3α), 4.15 (1H, d, J = 3 Hz, H-4α), 5.72 (1H, d, J = 3 Hz, H-6); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 19.6 (C-11), 21.0 (C-19), 21.8 (C-15), 25.1 (C-2), 30.9 (C-7), 31.3 (C-12), 31.4 (C-8), 35.8 (C-16), 36.1 (C-10), 36.9 (C-1), 47.6 (C-13), 50.2 (C-9), 51.8 (C-14), 72.3 (C-3), 77.1 (C-4), 127.8 (C-6), 142.8 (C-5), 221.4 (C-17).

Elution with ethyl acetate afforded 3β,6β-dihydroxyandrost-4-en-17-one (**11**) (107 mg, 0.351 mmol, 5.6%), which crystallized from ethyl acetate-methanol as amorphous crystals, m.p. 245–251°C (sublimed at 202°C), $[\alpha]_D$ + 100° (c = 0.05, MeOH), lit.[19] m.p. 274–276°C; IR ν_{max} 3250, 1720 cm^{-1}; ^{1}H NMR (CD_3OD) δ 0.94 (3H, s, H-18), 1.30 (3H, s, H-19), 4.08 (1H, m, w/2 = 16 Hz, H-3α), 4.18 (1H, b s, H-6α), 5.50 (1H, b s, H-4); ^{13}C NMR (CD_3OD) δ 14.4 (C-18), 21.2 (C-11), 21.9 (C-19), 22.6 (C-15), 29.6 (C-2), 31.1 (C-8), 32.6 (C-12), 36.6 (C-16), 38.0 (C-10), 38.2 (C-7), 39.2 (C-1), 48.5 (C-13), 52.1 (C-14), 55.8 (C-9), 68.3 (C-3), 74.4 (C-6), 130.0 (C-4), 147.5 (C-5), 223.6 (C-17).

Treibs oxidation of 3α-acetoxyandrost-5-en-17-one (22)

A stirred suspension of mercury(II) oxide (326 mg, 1.51 mmol) in dichloromethane (20 mL) was treated with trifluoroacetic anhydride (0.26 mL, 1.87 mmol). 3α-Acetoxyandrost-5-en-17-one (**22**) (201 mg, 0.608 mmol) was added and the solution was stirred for 2.5 h. The reaction mixture was filtered through celite and the filtrate was washed with saturated sodium hydrogen carbonate solution and dried. Evaporation of the solvent in vacuo produced an off-white foam (206 mg). Chromatography (15% acetone-petrol) gave unreacted starting material (10 mg, 0.030 mmol, 4.9%) followed by 3α-acetoxy-6-chloromercuriandrost-5-en-17-one (**24**) (61 mg, 0.108 mmol, 18%), which crystallized from the above-mentioned solvent system as plates, m.p. 173–174°C, $[\alpha]_D$ 0° (c = 0.05); IR ν_{max} 1737, 1698, 1256, 1231 cm^{-1}; Combustion analysis: Found: C, 44.53%; H, 5.07%. ($C_{21}H_{29}ClHgO_3$ requires C, 44.60%; H, 5.17%); MS (EI) m/z (%) 506.1305 (5), 270.1946 (25), 269.1903 (100), 105.0709 (13), 91.0550 (14), 81.0719 (28). ($C_{21}H_{29}{}^{35}Cl^{202}HgO_3$ − CH_3CO_2H requires 506.1300); ^{1}H NMR ($CDCl_3$) δ 0.88 (3H, s, H-18), 1.14 (3H, s, H-19), 2.05 (3H, s, CH_3CO_2), 5.03 (1H, t, J = 2.5 Hz, H-3β); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 19.6 (C-19), 20.0 (C-11), 21.4 ($\underline{C}H_3CO_2$), 21.7 (C-15), 25.9 (C-2), 31.2 (C-12), 33.2 (C-8), 33.6 (C-1), 35.8 (C-16), 40.2 (C-7), 41.2 (C-10), 42.9 (C-4), 47.5 (C-13), 49.4 (C-9), 51.6 (C-14), 70.3 (C-3), 145.6 (C-6), 145.6 (C-5), 170.6 ($CH_3\underline{C}O_2$), 220.5 (C-17).

Further elution with 25% acetone-petrol yielded 3α-acetoxy-6β-hydroxyandrost-4-en-17-one (**23**) (11 mg, 0.029 mmol, 4.8%), which was recrystallized from acetone-petrol to give very small needles, m.p. 165–166°C, $[\alpha]_D$ + 157° (c = 0.09); IR ν_{max} 3400, 1730, 1240 cm^{-1}; MS (CI NH_3) m/z (%) 364 (M^+, 91), 329 (69), 286 (100), 269 (74). ($C_{21}H_{30}O_4NH_4$ requires 364); ^{1}H NMR ($CDCl_3$) δ 0.94 (3H, s, H-18), 1.23 (3H, s, H-19), 2.05 (3H, s, CH_3CO_2), 4.30 (1H, t, J = 3 Hz, H-6α), 5.18 (1H, m, w/2 = 9 Hz, H-3β), 5.70 (1H, d, J = 5 Hz, H-4); ^{13}C NMR ($CDCl_3$) δ 13.8 (C-18), 20.4 (C-19), 20.6 (C-11), 21.4 ($\underline{C}H_3CO_2$), 21.7 (C-15), 24.8 (C-2), 29.6 (C-8), 31.4 (C-12), 33.1 (C-1), 35.8 (C-16), 36.9 (C-10), 37.5 (C-7), 47.7 (C-13), 51.0 (C-14), 53.6 (C-9), 66.6 (C-3), 74.0 (C-6), 122.6 (C-4), 151.6 (C-5), 170.8 ($CH_3\underline{C}O_2$), 221.0 (C-17).

Elution with 50% acetone-petrol afforded a mixture that was rechromatographed (30% acetone-toluene) on a silica-gel–coated glass plate to give 3α,6β-dihydroxyandrost-4-en-17-one (**25**) (18 mg, 0.059 mmol, 9.7%), which crystallized from dichloromethane as tiny needles, m.p. 194.5–197°C, $[\alpha]_D$ + 178° (c = 0.09), lit.[20] m.p. 218–221°C; IR ν_{max} 3444, 1725, 1031 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.92 (3H, s, H-18), 1.20 (3H, s, H-19), 4.16 (1H, b s, H-3β), 4.29 (1H, t, J = 3 Hz, H-6α), 5.74 (1H, d, J = 5 Hz, H-4); ^{13}C NMR ($CDCl_3$) δ 13.7 (C-18), 20.4 (C-19), 20.6 (C-11), 21.7 (C-15), 27.7 (C-2), 29.6 (C-8), 31.4 (C-12), 32.4 (C-1), 35.8 (C-16), 37.0 (C-10), 37.6 (C-7), 47.7 (C-13), 51.0 (C-14), 53.8 (C-9), 63.6 (C-3), 74.2 (C-6), 126.5 (C-4), 149.2 (C-5), 221.1 (C-17).

Treibs oxidation of 3β-bromoandrost-5-en-17-one (27)

Mercury(II) oxide (1.85 g, 8.54 mmol) and trifluoroacetic anhydride (1.50 mL, 10.7 mmol) were stirred together in dichloromethane (120 mL). 3β-Bromoandrost-5-en-17-one (**27**) (1.20 g, 3.42 mmol) was added and the solution was stirred for 24 h. The reaction mixture was filtered through celite and the clear brown filtrate was treated with sodium hydrogen carbonate solution and dried. Evaporation of the solvent in vacuo gave a yellow foam (1.25 g), which was chromatographed (10% ethyl acetate in petrol) to yield 3β-trifluoroacetoxyandrost-5-en-17-one (**18**) (180 mg, 0.468 mmol, 14%), which crystallized from acetone as very small prisms, m.p. 169–170°C, $[\alpha]_D$ − 11° (c = 0.11); IR ν_{max} 1778, 1741, 1230, 1169 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.19 (3H, s, H-19), 4.82 (1H, m, w/2 = 22 Hz, H-3α), 5.46 (1H, d, J = 4 Hz, H-6); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 19.2 (C-19), 20.3 (C-11), 21.8 (C-15), 27.2 (C-2), 30.7 (C-7), 31.3 (C-12), 31.4 (C-8), 35.8 (C-16), 36.6 (C-10), 36.6 (C-1), 37.4 (C-4), 47.5 (C-13), 50.0 (C-9), 51.6 (C-14), 78.4 (C-3), 114.5 (q, J = 285.8 Hz, $\underline{C}F_3CO_2$), 123.0 (C-6), 138.7 (C-5), 156.8 (q, J = 41.9 Hz, $CF_3\underline{C}O_2$), 220.9 (C-17).

Elution with 35% ethyl acetate in petrol gave 3β-hydroxyandrost-5-en-17-one (**17**) (204 mg, 0.707 mmol, 21%), which crystallized from ethyl acetate as needles, m.p. 169–170°C, $[\alpha]_D$ + 4° (c = 0.10), lit.[5] m.p. 168–169°C, $[\alpha]_D$ + 3.9°; IR ν_{max} 3450, 1725 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.91 (3H, s, H-18), 1.02 (3H, s, H-19), 2.75 (1H, s, OH), 3.55 (1H, m, w/2 = 24 Hz, H-3α), 5.38 (1H, d, J = 4 Hz, H-6); ^{13}C NMR ($CDCl_3$) δ 13.3 (C-18), 19.2 (C-19), 20.1 (C-11), 21.6 (C-15), 30.5 (C-7), 31.2 (C-2), 31.2 (C-8), 31.2 (C-12), 35.6 (C-16), 36.4 (C-10), 37.0 (C-1), 41.6 (C-4), 47.3 (C-13), 50.0 (C-9), 51.5 (C-14), 71.0 (C-3), 120.3 (C-6), 141.0 (C-5), 221.1 (C-17).

Further elution produced androst-4-ene-3,17-dione (**15**) (15 mg, 0.052 mmol, 1.5%), which was identified by its NMR data.

Treibs oxidation of 3β-chloroandrost-5-en-17-one (28)

Mercury(II) oxide (4.41 g, 20.4 mmol) and trifluoroacetic anhydride (3.5 mL, 24.8 mmol) were stirred together in dichloromethane (250 mL). 3β-Chloroandrost-5-en-17-one (**28**) (2.50 g, 8.15 mmol) was added and the solution was stirred for 24 h. The reaction mixture was filtered through celite to remove the powdery beige precipitate that had formed. The dark-brown filtrate was washed with saturated sodium bicarbonate solution and dried. The

solvent was removed under reduced pressure to give a brown foam (1.23 g), which was chromatographed. Elution (20% ethyl acetate in petrol) gave 3β-hydroxyandrost-5-en-17-one (**17**) (705 mg, 2.44 mmol, 30%), which was identified by its spectral data. Further elution afforded 4-chloromercuriandrost-4-ene-3,17-dione (**31**) (23 mg, 0.044 mmol, 0.5%), which crystallized from acetone-petrol as needles, m.p. 207–215°C (dec.), $[\alpha]_D$ + 200° (c = 0.13); UV (EtOH) λ_{max} 227 nm, log ε = 3.92; IR ν_{max} 1730, 1644 cm^{-1}; MS (CI NH_3) m/z (%) 544 (1), 543 (1), 542 (5), 541 (4), 540 (M^+, 13) 539 (7), 538 (8), 537 (6), 536 (3), 506 (3), 505 (3), 504 (13), 503 (7), 502 (11), 287 (100), 286 (71), 285 (36). ($C_{19}H_{25}{}^{35}Cl^{202}HgO_2NH_4$ requires 540); ^1H NMR ($CDCl_3$) δ 0.94 (3H, s, H-18), 1.26 (3H, s, H-19); ^{13}C NMR ($CDCl_3$) δ 13.7 (C-18), 18.2 (C-19), 20.6 (C-11), 21.7 (C-15), 30.9 (C-12), 31.7 (C-7), 34.2 (C-2), 35.3 (C-8), 35.5 (C-1), 35.7 (C-16), 37.7 (C-6), 42.1 (C-10), 47.4 (C-13), 50.7 (C-14), 54.1 (C-9), 148.4 (C-4), 175.7 (C-5), 199.7 (C-3), 220.2 (C-17).

Further elution afforded 6-chloromercuri-3β-hydroxyandrost-5-en-17-one (**29**) (10 mg, 0.019 mmol, 0.2%), which crystallized from acetone-petrol as needles, m.p. 195–197°C (dec.), $[\alpha]_D$ + 67° (c = 0.09), lit.[21] m.p. 210–212°C; IR ν_{max} 3450, 1722 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.12 (3H, s, H-19), 3.62 (1H, m, w/2 = 30 Hz, H-3α); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 20.1 (C-19), 20.3 (C-11), 21.7 (C-15), 31.2 (C-2), 31.2 (C-12), 33.2 (C-8), 35.8 (C-16), 37.1 (C-1), 40.2 (C-7), 40.7 (C-10), 47.5 (C-13), 48.6 (C-4), 49.6 (C-9), 51.5 (C-14), 71.0 (C-3), 145.3 (C-6), 147.5 (C-5), 220.6 (C-17).

Elution with 40% ethyl acetate in petrol produced 6β-hydroxyandrost-4-ene-3,17-dione (**30**) (67 mg, 0.221 mmol, 2.7%), which crystallized from acetone-petrol as small amorphous crystals, m.p. 186–187°C, $[\alpha]_D$ + 122° (c = 0.11), lit.[22] m.p. 193.5–194.5°C, $[\alpha]_D$ + 109°; UV (EtOH) λ_{max} 228 nm, log ε = 4.13; IR ν_{max} 3450, 1730, 1670 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.87 (3H, s, H-18), 1.33 (3H, s, H-19), 4.34 (1H, t, J = 3 Hz, H-6α), 5.76 (1H, s, H-4); ^{13}C NMR ($CDCl_3$) δ 13.7 (C-18), 19.5 (C-19), 20.2 (C-11), 21.7 (C-15), 29.4 (C-8), 31.2 (C-12), 34.1 (C-2), 35.7 (C-16), 37.0 (C-1), 37.2 (C-7), 38.0 (C-10), 47.6 (C-13), 50.9 (C-14), 53.6 (C-9), 72.7 (C-6), 126.4 (C-4), 168.0 (C-5), 200.3 (C-3), 220.5 (C-17).

Further elution afforded 3α,6β-dihydroxyandrost-4-en-17-one (**25**) (67 mg, 0.220 mmol, 2.7%), which was identified by its ^1H and ^{13}C NMR data.

Treibs oxidation of 3β-methoxyandrost-5-en-17-one (34)

Mercury(II) oxide (1.43 g, 6.60 mmol) and trifluoroacetic anhydride (1.2 mL, 8.5 mmol) were stirred together in dichloromethane (80 mL). 3β-Methoxyandrost-5-en-17-one (**34**) (0.80 g, 2.64 mmol) was added and the solution was stirred for 24 h. The reaction mixture was filtered through celite to remove the precipitated mercury(I) salts. The filtrate was washed with saturated sodium hydrogen carbonate solution and dried. Removal of solvent in vacuo yielded a yellow-brown gum (0.94 g), which was chromatographed. Elution with 25% ethyl acetate in petrol gave unreacted starting material (80 mg, 0.264 mmol, 10%) followed by 6-chloromercuri-3β-methoxy-androst-5-en-17-one (**36**) (68 mg, 0.127 mmol, 4.8%), which crystallized from acetone as rhomboids, m.p. 225–228°C (dec.), $[\alpha]_D$ − 10° (c = 0.11); IR ν_{max} 1730, 1099 cm^{-1}; MS (EI) m/z (%) 538.1559 (M^+, 12), 270.1949 (25), 269.1907 (100), 227.1436 (23), 91.0548 (25), 71.0499 (42). ($C_{20}H_{29}{}^{35}Cl^{202}HgO_2$ requires 538.1562); ^1H NMR ($CDCl_3$) δ 0.85 (3H, s, H-18), 1.06 (3H, s, H-19), 3.09 (1H, m, w/2 = 21 Hz, H-3α), 3.32 (3H, s, CH_3O); ^{13}C NMR ($CDCl_3$) δ 13.5 (C-18), 20.0 (C-19), 20.3 (C-11), 21.7 (C-15), 27.4 (C-2), 31.3 (C-12), 33.2 (C-8), 35.8 (C-16), 36.9 (C-1), 40.3 (C-7), 41.0 (C-10), 45.5 (C-4), 47.5 (C-13), 49.6 (C-9), 51.5 (C-14), 55.7 (CH_3O), 79.4 (C-3), 145.3 (C-5), 147.4 (C-6), 220.3 (C-17).

Further elution afforded androst-4-ene-3,17-dione (**15**) (49 mg, 0.171 mmol, 6.5%), which was identified by a comparison of its spectral data with that of an authentic sample. Elution with 35% ethyl acetate in petrol yielded 6β-hydroxy-3β-methoxyandrost-4-en-17-one (**35**) (52 mg, 0.163 mmol, 6.2%) as a brown gum that resisted crystallization, IR ν_{max} 3425, 1720 cm^{-1}; MS (EI) m/z (%) 318.2191 (M^+, 47), 286.1929 (34), 233.1540 (43), 85.0656 (82), 84.0581 (100). ($C_{20}H_{30}O_3$ requires 318.2194); ^1H NMR ($CDCl_3$) δ 0.90 (3H, s, H-18), 1.25 (3H, s, H-19), 3.36 (3H, s, CH_3O), 3.71 (1H, t, J = 9 Hz, H-3α), 4.25 (1H, s, H-6α), 5.58 (1H, s, H-4); ^{13}C NMR ($CDCl_3$) δ 13.8 (C-18), 20.2 (C-11), 21.4 (C-19), 21.7 (C-15), 25.0 (C-2), 29.9 (C-8), 31.4 (C-12), 35.8 (C-16), 36.6 (C-1), 37.1 (C-10), 37.6 (C-7), 47.7 (C-13), 51.2 (C-14), 54.3 (C-9), 55.8 (CH_3O), 73.9 (C-6), 76.3 (C-3), 126.5 (C-4), 147.5 (C-5), 221.2 (C-17).

Further elution gave 6β-hydroxyandrost-4-ene-3,17-dione (**30**) (40 mg, 0.132 mmol, 5.0%), which was identified by a comparison of its data with that of an authentic sample.

Treibs oxidation of androst-5-en-17-one (37)

Mercury(II) oxide (5.47 g, 25.3 mmol) and trifluoroacetic anhydride (4.50 mL, 31.9 mmol) were stirred together in dichloromethane (280 mL). Androst-5-en-17-one (**37**) (2.75 g, 10.1 mmol) was added and the solution was stirred for 22 h. The mixture was filtered through celite to remove the mercurous deposits. The clear, dark-green filtrate was washed with saturated sodium bicarbonate solution and dried. The solvent was removed on a rotary evaporator and the resultant yellow-orange foam (3.34 g) was chromatographed. Elution with 5.5% ethyl acetate in petrol yielded androst-5-ene-7,17-dione (**38**) (186 mg, 0.649 mmol, 6.4%), which crystallized from acetone as plates, m.p. 178–178.5°C, $[\alpha]_D$ − 143° (c = 0.07), lit.[23] m.p. 180–181°C, $[\alpha]_D$ − 116°; UV (EtOH) λ_{max} 234 nm, log ε = 4.08; IR ν_{max} 1741, 1661 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.91 (3H, s, H-18), 1.21 (3H, s, H-19), 5.71 (1H, s, H-6); ^{13}C NMR ($CDCl_3$) δ 13.7 (C-18), 17.4 (C-19), 20.1 (C-11), 21.9 (C-2), 24.2 (C-15), 26.7 (C-3), 30.7 (C-12), 32.7 (C-4), 35.6 (C-16), 39.0 (C-1), 39.3 (C-10), 44.3 (C-8), 45.7 (C-14), 47.9 (C-13), 50.4 (C-9), 124.4 (C-6), 169.6 (C-5), 201.3 (C-7), 220.6 (C-17).

Elution with 25% ethyl acetate in petrol afforded androst-4-ene-3,17-dione (**15**) (83 mg, 0.290 mmol, 2.9%), which was identified by comparison with an authentic sample. Further extensive chromatography (40% ethyl acetate in petrol) gave 3β,6β-dihydroxyandrost-4-en-17-one (**11**) (396 mg, 1.32 mol, 13%), which was identified by a comparison of its spectral data with that of an authentic sample.

3β-Acetoxy-6β-trifluoroacetoxyandrost-4-en-17-one (6a) and 3β-acetoxy-4β-trifluoroacetoxyandrost-5-en-17-one (39)

Trifluoroacetic anhydride (130 μL, 0.935 mmol) was added to a stirred suspension of mercury(II) oxide (163 mg, 0.752 mmol) in dichloromethane (10 mL). 3β-Acetoxyandrost-5-en-17-one (**1a**) (100 mg, 0.303 mmol) was added and the solution was stirred for 24 h. The reaction mixture was filtered through celite and the filtrate was evaporated to dryness in vacuo. The residue was chromatographed (twice developed in 20% acetone in petrol) on a silica-gel–coated plate and yielded the following compounds in order of increasing polarity: 3β-acetoxy-4β-trifluoroacetoxyandrost-5-en-17-one (**39**) (1 mg, 0.002 mmol, 0.7%), which did not crystallize, IR ν_{max} 1770, 1730, 1240, 1170 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.89 (3H, s, H-18), 1.16 (3H, s, H-19), 2.02 (3H, s,

CH_3CO_2), 4.84 (1H, dt, J = 12, 4 Hz, H-3α), 5.68 (1H, d, J = 2 Hz, H-4α), 5.96 (1H, dd, J = 2, 4 Hz, H-6); 3β-acetoxy-6β-trifluoroacetoxyandrost-4-en-17-one (**6a**) (26 mg, 0.059 mmol, 20%), which resisted crystallization, IR ν_{max} 1770, 1730, 1240, 1170 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.98 (3H, s, H-18), 1.23 (3H, s, H-19), 2.13 (3H, s, CH_3CO_2), 5.25 (1H, dt, J = 3, 8 Hz, H-3α), 5.53 (1H, t, J = 3 Hz, H-4), 5.80 (1H, t, J = 2 Hz, H-6α); ^{13}C NMR ($CDCl_3$) δ 13.6 (C-18), 19.8 (C-11), 20.2 (C-19), 21.1 ($\underline{C}H_3CO_2$), 21.6 (C-15), 24.2 (C-2), 30.2 (C-8), 30.9 (C-12), 35.3 (C-16), 35.7 (C-1), 36.2 (C-10), 36.6 (C-7), 48.1 (C-13), 50.5 (C-14), 53.3 (C-9), 70.6 (C-3), 79.5 (C-6), 114.4 (q, J = 286.4 Hz, $\underline{C}F_3CO_2$), 130.0 (C-4), 141.7 (C-5), 156.3 (q, J = 42.3 Hz, $CF_3\underline{C}O_2$), 172.5 ($CH_3\underline{C}O_2$), 224.1 (C-17), and 3β-acetoxy-6-chloromercuriandrost-5-en-17-one (**4a**) (28 mg, 0.050 mmol, 17%), which was identified by comparison with an authentic sample. The trifluoroacetates **6a** and **39** were dissolved in dichloromethane and the respective solutions were treated with saturated sodium hydrogen carbonate solution and water. The steroids were recovered unchanged.

Reaction of mercury(II) trifluoroacetate with dichloromethane

Mercury(II) oxide (3.02 g, 14.0 mmol) and trifluoroacetic anhydride (2.4 mL, 17.2 mmol) were stirred together in dichloromethane (200 mL). A white precipitate started depositing slowly after 1 week. The mixture was left to stand for 1 month to allow the reaction to go to completion. The precipitate was collected by vacuum filtration, washed with dichloromethane to remove any traces of mercury(II) trifluoroacetate and quickly sucked dry. The compound was identified as chloromercury(II) trifluoroacetate (3.50 g, 10.0 mmol, 71%), m.p. 263–265°C (dec.); IR ν_{max} 1700, 1215, 1130 cm^{-1}; MS (EI) m/z (%) 353.9246 (6), 352.9273 (1), 351.9240 (44), 350.9223 (14), 349.9235 (M^+, 100), 348.9228 (51), 347.9217 (71), 346.9222 (45), 345.9206 (27). ($C_2{}^{35}ClF_3{}^{202}HgO_2$ requires 349.9245).

*Treibs oxidation of 3β-acetoxyandrost-5-en-17-one (**1a**) in dibromomethane*

Mercury(II) oxide (1.63 g, 7.57 mmol) and trifluoroacetic anhydride (1.3 mL, 9.2 mmol) were stirred together in dibromomethane (100 mL). 3β-Acetoxyandrost-5-en-17-one (**1a**) (1.00 g, 3.03 mmol) was introduced after 10 min and the solution was stirred for 24 h. A precipitate of mercury(I) trifluoroacetate was seen after 1 h. The reaction mixture was filtered through celite and the mercurous salt residue was rinsed with ethyl acetate (which dissolved it) and the washings were added to the filtrate. The organic solution was treated with a saturated solution of sodium hydrogen carbonate and was dried with calcium sulfate. Removal of the solvents on the rotary evaporator gave a dark-yellow foam (0.99 g), which was chromatographed (15% ethyl acetate in petrol) to give unreacted starting material (32 mg, 0.097 mmol, 3.2%). Elution with 20% ethyl acetate in petrol afforded 3β-acetoxy-6-bromomercuriandrost-5-en-17-one (**40**) (35 mg, 0.056 mmol, 1.8%), which crystallized from ethyl acetate-petrol as amorphous crystals, m.p. 213.5–220°C (dec.), $[\alpha]_D$ 0° (c = 0.02); IR ν_{max} 1720, 1240 cm^{-1}; MS (CI NH_3) m/z (%) 632 (3), 631 (4), 630 (18), 629 (11), 628 (M^+, 25), 627 (16), 626 (16), 625 (9), 624 (5), 348 (100), 270 (53). ($C_{21}H_{29}{}^{79}Br^{202}HgO_3NH_4$ requires 628); ^1H NMR (C_6D_6) δ 0.68 (3H, s, H-18), 0.82 (3H, s, H-19), 1.80 (3H, s, CH_3CO_2), 4.72 (1H, m, w/2 = 20 Hz, H-3α); ^{13}C NMR (C_6D_6) δ 13.3 (C-18), 19.8 (C-19), 20.4 (C-11), 21.0 ($\underline{C}H_3CO_2$), 21.9 (C-15), 27.8 (C-2), 31.8 (C-12), 32.9 (C-8), 35.6 (C-16), 37.0 (C-1), 39.9 (C-10), 40.5 (C-7), 44.0 (C-4), 47.3 (C-13), 49.5 (C-9), 51.4 (C-14), 73.0 (C-3), 144.3 (C-6), 144.3 (C-5), 169.8 ($CH_3\underline{C}O_2$), 217.8 (C-17).

Further elution yielded 3β-acetoxy-6-chloromercuriandrost-5-en-17-one (**4a**) (48 mg, 0.085 mmol, 2.8%), which was identified by comparison with an authentic sample. Elution with 30% ethyl acetate in petrol gave 3β-acetoxy-6β-hydroxyandrost-4-en-17-one (**7a**) (302 mg, 0.872 mmol, 29%), which was identified by comparison with an authentic sample.

*Reaction of mercury(II) trichloroacetate with 3β-acetoxyandrost-5-en-17-one (**1a**)*

Mercury(II) oxide (82 mg, 0.379) mmol was stirred with trichloroacetic acid (73 mg, 0.447 mmol) in dichloromethane (5 mL) for 1 h. 3β-Acetoxyandrost-5-en-17-one (**1a**) (50 mg, 0.151 mmol) was added to the clear, green solution and the mixture was stirred for 22 h. The reaction mixture, which now contained a white deposit, was filtered through celite and the filtrate was washed with saturated sodium hydrogen carbonate solution and dried. The solvent was evaporated under reduced pressure to afford an off-white residue (65 mg), which was chromatographed (10% acetone-petrol) to yield unreacted starting material (7 mg, 0.021 mmol, 14%), 3β-acetoxy-6-chloromercuriandrost-5-en-17-one (**4a**) (18 mg, 0.032 mmol, 21%), and 3β-acetoxy-6β-hydroxyandrost-4-en-17-one (**7a**) (7 mg, 0.020 mmol, 13%). All the compounds were identified by their spectral data.

*Reaction of mercury(II) tribromoacetate with 3β-acetoxyandrost-5-en-17-one (**1a**)*

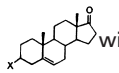
Mercury(II) oxide (164 mg, 0.757 mmol) and tribromoacetic acid (225 mg, 0.757 mmol) were stirred together in dichloromethane (10 mL) for 2 h. Both reagents dissolved and were replaced by a white solid (presumably mercury(II) tribromoacetate). 3β-Acetoxyandrost-5-en-17-one (**1a**) (100 mg, 0.303 mmol) was added and the mixture was stirred for 2 days. Thin-layer chromatography indicated that the starting material had not reacted. The solvent was removed in vacuo, replaced with acetic acid (10 mL) and the mixture was heated at 90°C for 5 h. Thin-layer chromatography data indicated the formation of a small amount of a less polar product. The mixture was heated under reflux for a further 10 h to enhance this reaction, but decomposition occurred at this higher temperature.

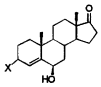
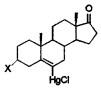
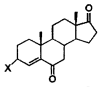
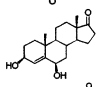
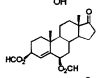
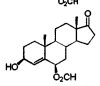
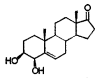
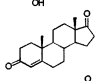
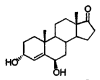
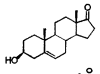
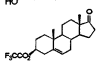
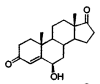
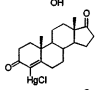
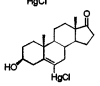
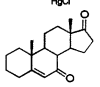
Results and discussion

The preparations of the substrates were done according to literature procedures.[5–15,24–31]

Treibs oxidation on the substrates

The reaction of 3β-acetoxyandrost-5-en-17-one (**1a**) with mercury(II) trifluoroacetate produced the 6β-hydroxy-Δ^4-derivative (**7a**)[1] as the major product (43% yield) along with the 6-ketone (**8a**)[16] and 3β-acetoxy-6-chloromercuriandrost-5-en-17-one (**4a**).[4] The reaction mechanism for the formation of the allylic alcohol (**7a**) is thought to involve electrophilic attack by the mercuric ion on the double bond of **1a** to give the 5α,6α-mercurinium ion (**2**)[32] (Scheme 1). Loss of the 4β-proton[3] leads to the allylic organomercurial (**5**),[33] which is substituted at C-6 by a trifluoroacetate anion. This S_N2 reaction is aided by a mercury(II)-assisted demercuration,[33] which leads to the formation of a precipitate of mercury(I) trifluoroacetate. Basic hydrolysis of **6** during

Table 1 Products and Percent Yields from the Reaction of  with Mercury(II) Trifluoroacetate in Dichloromethane

	Substrates										
Products	X = 3β-CH_3CO_2 (%)	X = 3β-$CH_3CH_2CO_2$ (%)	X = 3β-$CH_3(CH_2)_2CO_2$ (%)	X = 3β-$(CH_3)_3CCO_2$ (%)	X = 3β-$CH_3CH_2OCO_2$ (%)	X = 3β HCO_2 (%)	X = 3α-CH_3CO_2 (%)	X = 3β-Br (%)	X = 3β Cl (%)	X = 3β MeO (%)	X = H (%)
	42	28	40	34	20	16	5.0	—	—	6.2	—
	6	2.9	2.9	2.2	6.5	—	18	—	—	4.8	—
	1.4	—	—	5.8	—	—	—	—	—	—	—
	—	—	—	—	—	5.6	—	—	—	—	13
	—	—	—	—	—	2.2	—	—	—	—	—
	—	—	—	—	—	1.8	—	—	—	—	—
	—	—	—	—	—	1.5	—	—	—	—	—
	—	—	—	—	—	1.1	—	1.5	—	6.5	2.9
	—	—	—	—	—	—	9.7	—	2.7	—	—
	—	—	—	—	—	—	—	21	30	—	—
	—	—	—	—	—	—	—	14	—	—	—
	—	—	—	—	—	—	—	—	2.7	5.0	—
	—	—	—	—	—	—	—	—	0.5	—	—
	—	—	—	—	—	—	—	—	0.2	—	—
	—	—	—	—	—	—	—	—	—	—	6.4
Recovered substrate	—	1.6	1.2	—	5.0	6.2	4.9	—	—	10	—

work-up affords the Δ^4-alcohol (**7a**). The ketone may have been formed through in situ oxidation of any **7a** formed before work-up. Loss of the 6-proton from intermediate **2** produces an alkenylmercuric trifluoroacetate (**3**), which reacts with dichloromethane to produce the alkenylmercuric chloride (**4a**). The replacement of the trifluoroacetate ligand in **3** by chloride from the solvent is a new reaction and represents a novel synthesis of compounds in this class. Previous syntheses involved treatment of the corresponding alkenylmercuric acetates with hydrogen chloride or alkali metal chlorides.[34,35] The high resolution mass spectral data for **4a** contained a cluster of peaks around m/z 506, i.e., 508.1290 (2%), 507.1287 (1%), 506.1280 (5%), 505.1275 (3%), 504.1265 (4%), and 503.1265 (2%). This depicted the

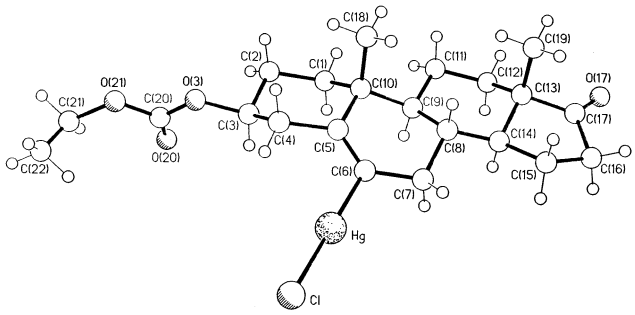
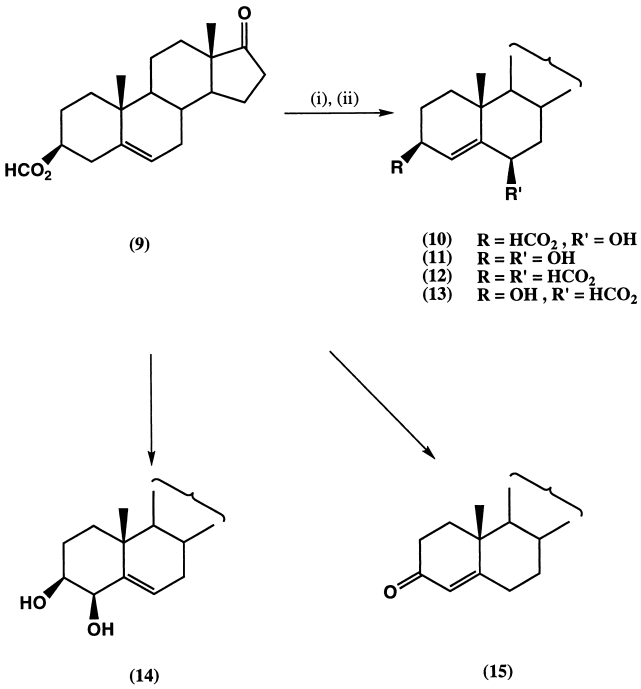


Fig. 1.

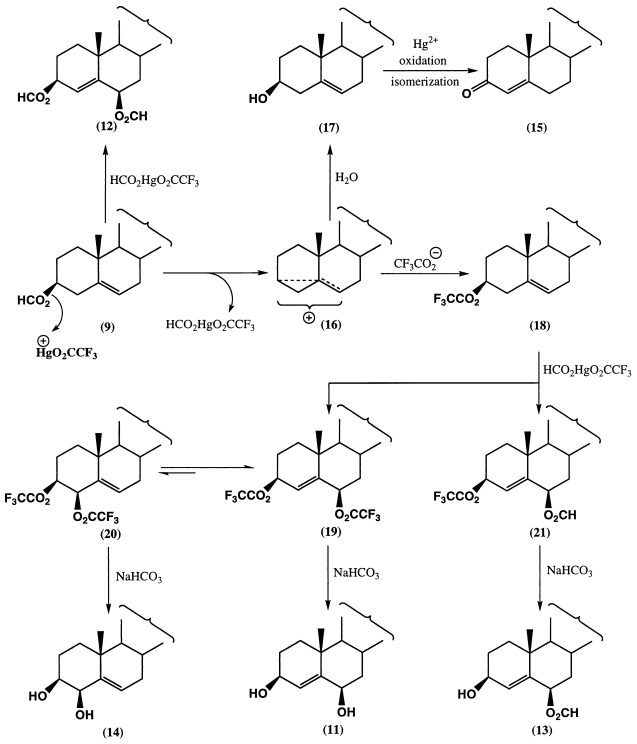
expected pattern of (mercury and chlorine containing) isotopomers for the compound after loss of acetic acid.

The other 3β-esters (**1b–1e**) also afforded 6β-hydroxy-Δ^4-derivatives (**7b–7e**) as the major products and gave alkenylmercuric chlorides (**4b–4e**) in small amounts (see Table 1). The structure of the mercury-containing compound **4e** derived from reaction with the 3β-ethyl carbonate (**1e**) was confirmed by single crystal x-ray analysis (see Figure 1). 3β-Pivaloxyandrost-5-en-17-one (**1d**) also gave the 6-ketone (**8b**) in 6% yield. These new steroids (**4a–4e**, **7b–7e**, and **8b**) gave satisfactory mass spectral and combustion analyses.

The formate ester (**9**) was converted to many compounds (Scheme 2) apart from the 6β-hydroxy-Δ^4-derivative (**10**), the major product (16%). 3β,6β-Dihydroxyandrost-4-en-17-one (**11**)[19] was obtained in 6% yield and was the next most abundant product. Interestingly the *di*formate (**12**) was also formed, probably via

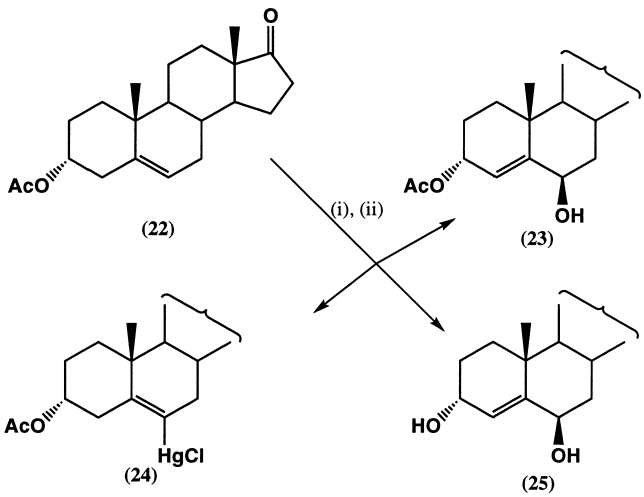


Scheme 2 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Cl_2$ (ii) aq. $NaHCO_3$.



Scheme 3

Treibs reaction on **9** by mercuric formate trifluoroacetate (see Scheme 3). Methine resonances (3β,6β-CHO) were seen at 160.1 and 160.7 ppm in the ^{13}C NMR spectrum. 6β-Formyloxy-3β-hydroxyandrost-4-en-17-one (**13**) absorbed in the IR spectrum at 3500 cm^{-1}. The ^{13}C NMR spectrum was similar to that of the diester (**12**), but only one aldehydic resonance was observed (160.4 ppm). The base peak at m/z = 350 in the mass spectral data (CI NH_3) was consistent with $[C_{20}H_{28}O_4 + NH_4]^+$. The diol (**14**)[18] and ketone (**15**)[17] were easily identified by their



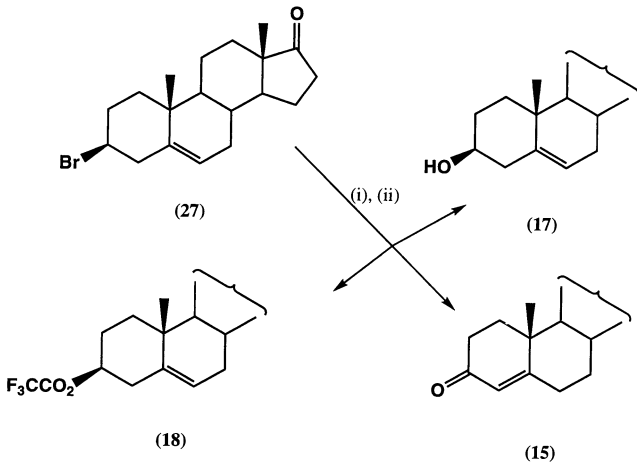
Scheme 4 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Cl_2$ (ii) aq. $NaHCO_3$.

spectral data. Possible explanations for the formation of the products are shown in Scheme 3. In many of the products, the C-3 formyl group was absent. The mercury cation functions as a Lewis acid in an $A_{AL}1$ type deformyloxylation of the starting material and forms the mixed mercuric salt (mercuric formate trifluoroacetate) en route to these compounds. This type of cleavage of the ester group is likely since the positive charge left at C-3 is stabilized by the electrons of the Δ^5 bond (see mesomeric cation [**16**]).[28]

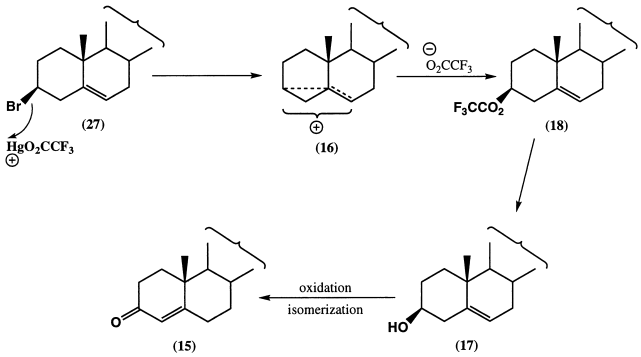
The effect of inversion of the stereochemistry at C-3 was ascertained when 3α-acetoxyandrost-5-en-17-one (**22**) was utilized as a substrate. While the 3β-esters (**1a–1e**) gave 6β-hydroxy-Δ^4-derivatives (**7a–7e**) as the major products, accompanied in most cases by small amounts of the mercury steroids (**4a–4e**), the 3α-acetate (**22**) provided a dramatic reversal in the product distribution. 3α-Acetoxy-6-chloromercuriandrost-5-en-17-one (**24**) was the major product (18% yield), while 3α-acetoxy-6β-hydroxyandrost-4-en-17-one (**23**) was obtained in 5% yield (Scheme 4). With the 3β-substituted esters, the formation of the Δ^4 compounds (**7a–7e**) from the mercurinium ion (**2**) may have been promoted by the proximity of the carbonyl oxygen of the ester group to the 4β-proton. Obvious stereochemical constraints in the 3α-acetate complex prevent this type of interaction. The polar 3α,6β-dihydroxysteroid (**25**)[20] was also obtained (10% yield) from **22**. The formation of the 3α-alcohol (**25**) may have involved a mercury ion catalyzed $A_{AC}2$ deacetylation[36] (Scheme 5). An $A_{AL}1$ deacetoxylation of the Δ^4-ester (**23**) would have yielded products epimeric at C-3.

3β-Bromoandrost-5-en-17-one (**27**) afforded the 3β-hydroxy analog (**17**) as the major product (21%). The trifluoroacetate (**18**) was produced in 14% yield (Scheme 6). The IR data showed two carbonyl stretches, the absorption at higher frequency (1778 cm^{-1}) being attributed to the trifluoroacetate group. Quartets at δ 114.5 and 156.8 in the fluorine coupled ^{13}C NMR spectrum were due to the trifluoroacetoxy group. Dione **15** was also obtained. The retention of configuration observed at C-3 indicates that the homoallylic cation (**16**) functions as the pivotal intermediate during the reaction of this substrate (**27**). The mechanism (Scheme 7) is likely to involve initial debromination of **27** by the mercury(II) trifluoroacetate cation. Attack by trifluoroacetate at C-3β of the resultant mesomeric cation (**16**) provides the ester (**18**), which is partially hydrolyzed on work-up to afford **17**.

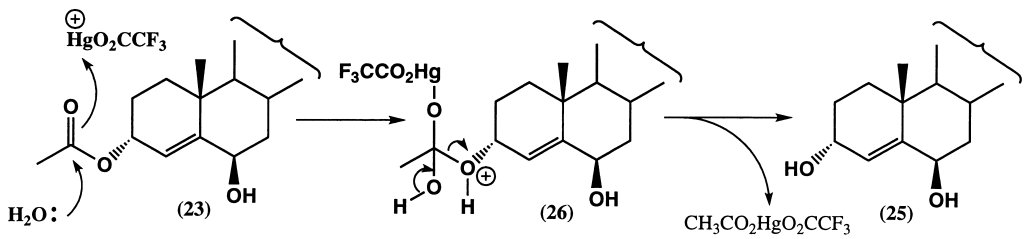
3β-Chloroandrost-5-en-17-one (**28**) also gave **17** as the major product (30% yield), along with a small amount of the mercurated derivative, 6-chloromercuri-3β-hydroxyandrost-5-en-17-one (**29**)[21] (Scheme 8). The diol (**25**), ketone (**30**), and 4-chloromercuriandrost-4-ene-3,17-dione (**31**) were also formed. Compound **25** was recognized by comparison with an authentic sample. The UV spectral data of 6β-hydroxyandrost-4-ene-3,17-dione (**30**)[22] (λ_{max} 228 nm) confirmed the presence of the conjugated system. The mercuristeroid **31** absorbed at 227 nm in the UV spectrum. The ^{13}C NMR spectrum was similar to that of androst-4-ene-3,17-dione (**15**), but showed chemical shifts consistent with a chloromercury



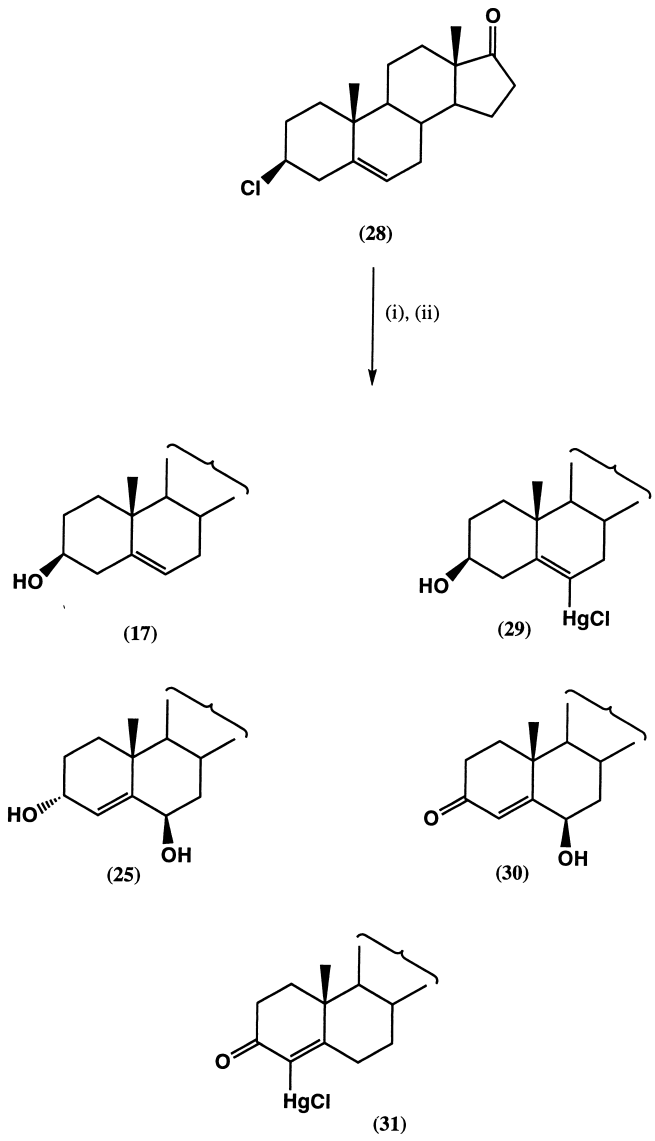
Scheme 6 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Cl_2$ (ii) aq. $NaHCO_3$.



Scheme 7



Scheme 5

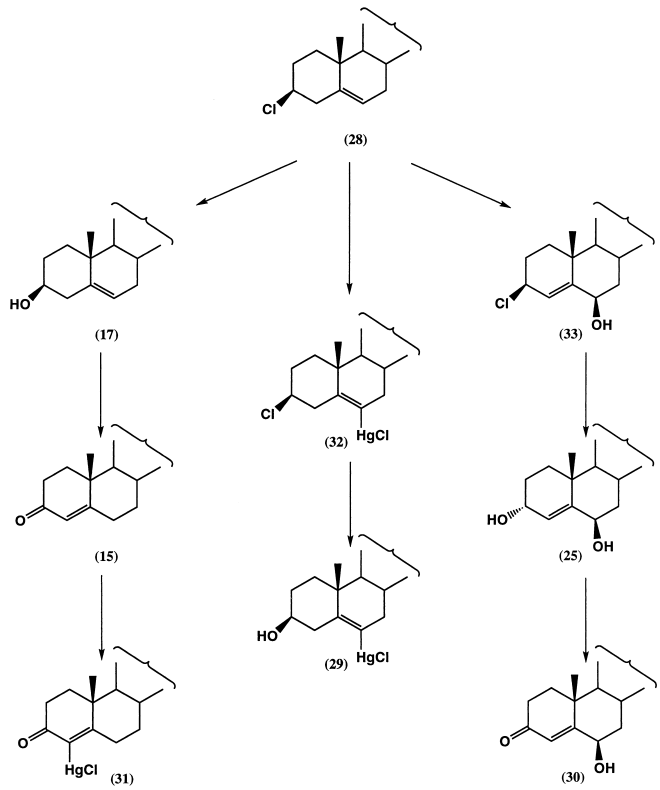


Scheme 8 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Cl_2$ (ii) aq. $NaHCO_3$.

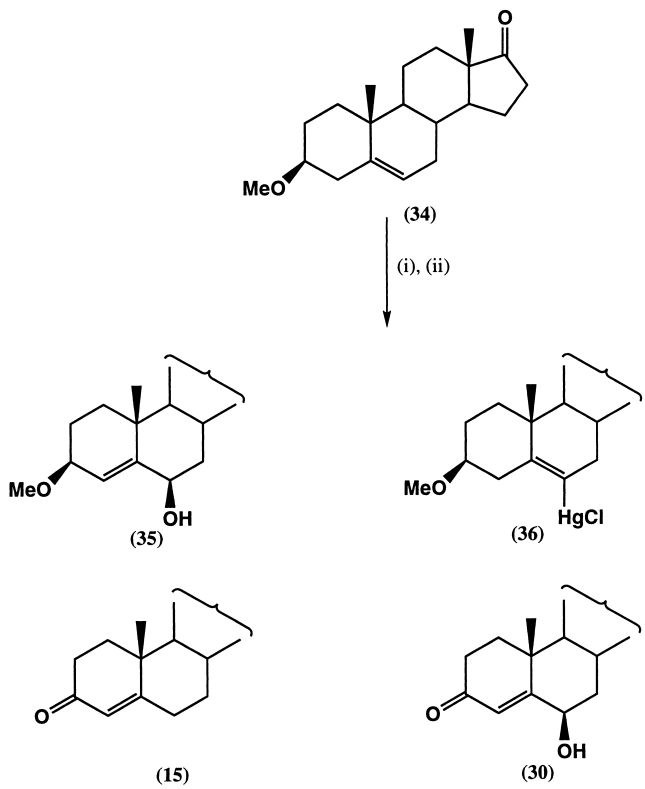
substituent[37] at C-4. The formation of the products is rationalized in Scheme 9.

The reaction of the methyl ether **34** afforded 6β-hydroxy-3β-methoxyandrost-4-en-17-one (**35**) along with the mercury steroid **36** (Scheme 10). α,β-Unsaturated ketones **15** (the major product) and **30** were also formed. The products were all obtained in 5–7% yields and had spectral data consistent with their structures. The mechanisms of product formation are likely to be along pathways already discussed.

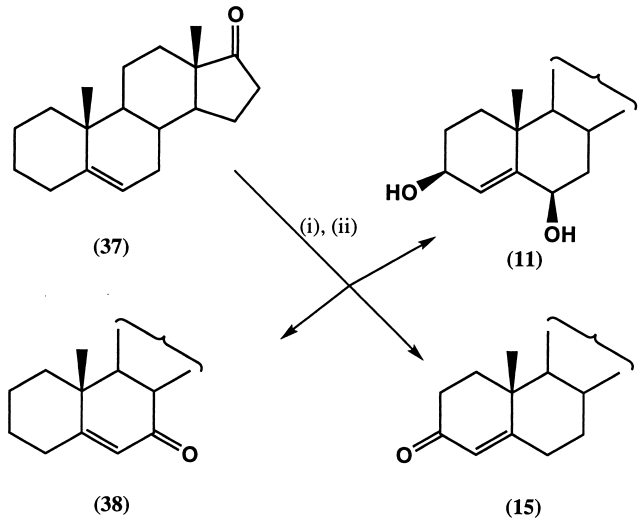
Androst-5-en-17-one (**37**) gave **11** as the major product in 13% yield (Scheme 11). The conjugated ketones **38** and **15** were also obtained. The 7-ketone (**38**)[23] absorbed strongly in the UV region of the spectrum and its IR data contained a new carbonyl stretch at 1661 cm^{-1}. Replacement of hydrogen by oxygen at C-3 and C-7 was a feature of the reaction of mercury(II) trifluoroacetate with this substrate (**37**).



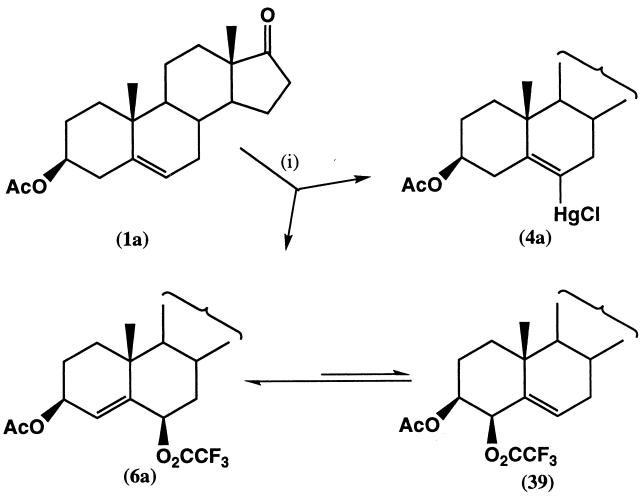
Scheme 9



Scheme 10 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Cl_2$ (ii) aq. $NaHCO_3$.



Scheme 11 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Cl_2$ (ii) aq. $NaHCO_3$.



Scheme 12 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Cl_2$.

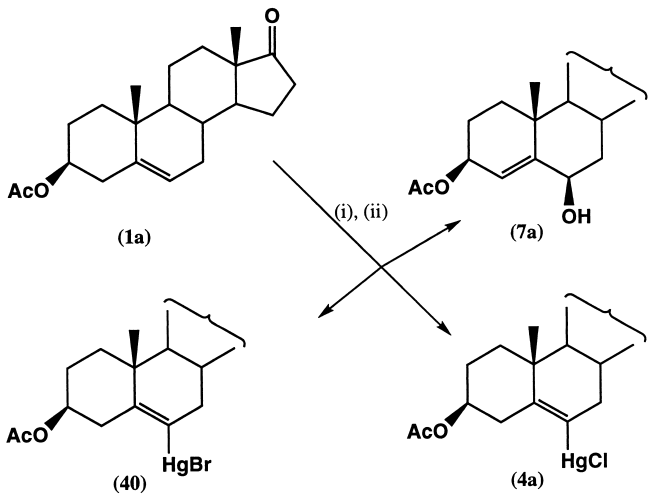
Isolation of reaction intermediates in the Treibs oxidation of the 3β-acetate (**1a**)

The mixture from the reaction of 3β-acetoxyandrost-5-en-17-one (**1a**) and mercuric trifluoroacetate was chromatographed without being subjected to treatment with saturated sodium hydrogen carbonate solution. The trifluoroacetate ester (**6a**) was isolated (Scheme 12) along with a trace amount of an isomeric compound (**39**). The mercurated steroid (**4a**) was also obtained. The IR data of the 6β-trifluoroacetate (**6a**) showed stretches typical of the carbonyl groups present. The 6α-proton absorbed at δ 5.80 in the NMR spectrum. The ^{13}C NMR spectrum had methine signals at 70.6 (C-3) and 79.5 ppm (C-6). The IR spectrum of **39** was similar to that of **6a**. The ^1H NMR spectrum contained signals at δ 4.84, 5.68, and 5.96, which were assigned to H-3α, H-4α and H-6, respectively. Treatment of a dichloromethane solution of the isolated diol monotrifluoroacetates **6a** and **39** with saturated sodium bicarbonate solution *in the absence of the mercury salt* did not result in their expected hydrolyses. This suggests that the hydrolysis of the 6β-trifluoroacetate (**6a**) that is observed under standard conditions is aided by dissolved mercury salts present in the reaction mixture. This provides some evidence for the proposal made earlier that the mercury(II) trifluoroacetate cation functioned as a Lewis acid in the hydrolysis of esters.

Variation of solvent

The use of chloroform and carbon tetrachloride as solvents resulted in the formation of the same products that were obtained in dichloromethane but only 50 and 20%, respectively, of the starting material (**1a**) reacted. Mercury(II) trifluoroacetate was more soluble in chloroform than in dichloromethane and only partially soluble in carbon tetrachloride. The ester (**1a**) did not react in methanol, diethyl ether, acetone, tetrahydrofuran, or benzene, although the mercuric salt dissolved completely in these solvents. A more effective solvation of $[HgO_2CCF_3]^+$ in chloroform, benzene and the oxygenated solvents may be responsible for the increased solubility of the salt, but also its lack of reactivity toward the substrate. Benzene may even have reacted with mercury(II) trifluoroacetate, since it is mercurated by the less electrophilic mercuric acetate.[38] It was observed that dichloromethane reacted with mercuric trifluoroacetate (in the absence of steroid). Chloromercury(II) trifluoroacetate precipitated slowly from solution. This reaction can be duplicated in refluxing chloroform. The IR spectrum of this previously unreported mercuric salt contained characteristic trifluoroacetate group absorptions. The mass spectral (EI) data showed a cluster of isotopomeric signals between 345.9206 and 353.9246, which included the base peak at m/z = 349.9235 ($C_2{}^{35}ClF_3{}^{202}HgO_2$ requires 349.9245). The products of the reaction support the proposal for the formation of the chloromercuristeroids (**4a–4e**), which involved similar interactions with the solvent (Scheme 1). Solvated mercurinium ions have been proposed[39] as intermediates in the mercuration of alkenes.

The use of dibromomethane afforded 3β-acetoxy-6-



Scheme 13 Reagents: (i) $Hg(O_2CCF_3)_2/CH_2Br_2$ (ii) aq. $NaHCO_3$.

bromomercuriandrost-5-en-17-one (**40**) as a minor product (Scheme 13), as well as the expected 6β-hydroxy steroid (**7a**). The IR, ^{1}H and ^{13}C NMR data of **40** were similar to those of the chloromercury analog (**4a**). The NMR spectra were run in deuterated benzene to preclude the possibility of halide exchange. Mass spectral data (CI NH_3) included a cluster of molecular ion peaks between m/z = 624 and 632. The largest signal in the group (for $[C_{21}H_{29}{}^{79}Br^{202}HgO_3 + NH_4]^+$) was seen at m/z = 628 (25%). The base peak $[C_{21}H_{29}{}^{79}Br^{202}HgO_3 + NH_4 - HgBr + H]^+$, was apparent at m/z = 348. The mechanism of formation involves the abstraction of a bromide ion from the solvent. Very surprisingly, the alkenylmercuric *chloride* (**4a**) was also obtained, and this indicated the presence of chloride ions in one or more of the reagents. Diiodomethane reacted with mercury(II) trifluoroacetate to give a mustard-colored precipitate. The deposit, perhaps iodomercury(II) trifluoroacetate, did not react appreciably with **1a**.

The application of microwave radiation to a solution of **1a** and mercuric trifluoroacetate in dichloromethane effected the total conversion of the starting material in 14 min. The substrate did not react under these conditions in benzene.

Variation of the mercury salt

Mercury(II) trichloroacetate, prepared by reacting mercuric oxide with trichloroacetic acid in dichloromethane, converted **1a** to the allylic alcohol (**7a**) and the alkenylmercuric chloride (**4a**). Thin-layer chromatographic analysis suggested that 3β-acetoxy-4β-trichloroacetoxyandrost-5-en-17-one and 3β-acetoxy-6β-trichloroacetoxyandrost-4-en-17-one were present in the reaction mixture before treatment with saturated sodium hydrogen carbonate solution. A greater recovery of starting material afforded the only significant difference from the standard reaction. Tribromoacetic acid reacted with mercuric oxide in dichloromethane to give a white solid, presumably mercury(II) tribromoacetate, which was unreactive toward **1a**.

The reaction of the 3-substituted androst-5-en-17-ones with mercury(II) trifluoroacetate gave many products (Table 1). Most of the compounds resulted from attack of the reagent on the Δ^5 bond of the substrates. However, products resulting from cleavage of the C-3 substituent by the mercury(II) trifluoroacetate cation were also obtained. The 3β-esters (**1a–1e**, **9**) gave the 6β-hydroxy-Δ^4 derivative as the major product. Chloromercury steroids were obtained, except in the case of the formate (**9**), as minor products. Both groups of compounds are potentially useful in the synthesis of biologically important steroids. Changes in the length and bulkiness of the alkyl group of the 3β-esters produced some variation in the yield, but no straightforward correlation between product yield and chain length has yet been established. The other substrates gave poorer yields of the 6β-hydroxy-Δ^4 derivative due in most cases to the competing cleavage reaction at C-3. Treibs oxidation of the 3α-acetate (**22**) afforded a reversal of the product distribution observed for the 3β-esters and may lead to a more general method of preparing chloromercury steroids in good yields.

The reaction was found to be solvent-sensitive and proceeded satisfactorily only in dichloro- and dibromomethane. Microwave radiation reduced the usual reaction time between **1a** and mercuric trifluoroacetate by 100-fold. Of the other mercury salts investigated, only mercury(II) trichloroacetate effected oxidation of the substrate.

In summary, the reaction of mercuric trifluoroacetate with the 3-substituted-Δ^5-steroids gave isolatable products in modest yields, with much of the steroid apparently going to a polymer that remains on the silica-gel column. This phenomenon is common in the reaction of similar substrates with mercuric salts.[32,40,41] Most of the products reported herein are new. A number of novel reactions were also identified, including those between mercury(II) trifluoroacetate and the halogenated solvents used.

Acknowledgments

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