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Synthesis of Some Analogues of Blattellastanoside A, the Steroidal Aggregation Pheromone of the German Cockroach†

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Abstract—Blattellastanoside A, the aggregation pheromone of the German cockroach, is a chlorinated steroid glucoside with the 5β-stigmastane skeleton. Its analogues were synthesized in order to clarify the structure–activity relationship. They are **1a** with the 5β-cholestane skeleton, **1b** with the 5β-androstane skeleton, **1c** with a fluorine substituent instead of the chlorine and **1d** with a β-D-galactopyranose instead of the β-D-glucopyranose of the original pheromone. Their bioassay shows that **1a** and **1c** are active, while **1b** and **1d** are totally devoid of pheromone activity. The aglycone of blattellastanosides A and B were active.

Introduction

The German cockroach (*Blattella germanica* L.) excretes the aggregation pheromone with its frass and marks its harboring place.[2,3] Recently, in 1990, Sakuma and Fukami identified the hydrochlorides of ammonia, methylamine, dimethylamine, trimethylamine and 1-dimethylamino-2-methyl-2-propanol as the attractant components of the aggregation pheromone.[4] The arrestant components were finally identified in 1993 by Sakuma and Fukami as blattellastanosides A and B (Scheme 1).[5,6] The correctness of the proposed structures of blattellastanosides A and B was confirmed by our synthesis.[7] These two cockroach pheromone components are quite unique as chlorinated steroidal glucosides with no volatility at all, which means that they are contact pheromones. Blattellastanoside A is reported to be 70 times more bioactive than B as the arrestant.

We became interested in synthesizing the analogues of blattellastanoside A in order to clarify the structure–activity relationship. This paper describes the synthesis of four analogues **1a–d** (Scheme 2) of blattellastanoside A. Compound **1a** is an analogue with the 5β-cholestane skeleton instead of the 5β-stigmastane skeleton of the original pheromone, while compound **1b** possesses the 5β-androstane skeleton. Compound **1c** is the fluorine analogue, and compound **1d** is the β-D-galactoside analogue of blattellastanoside A. A preliminary bioassay revealed that **1a** and **1c** are active, while **1b** and **1d** are inactive.

†Pheromone Synthesis, Part 172. For Part 171, see ref 1.

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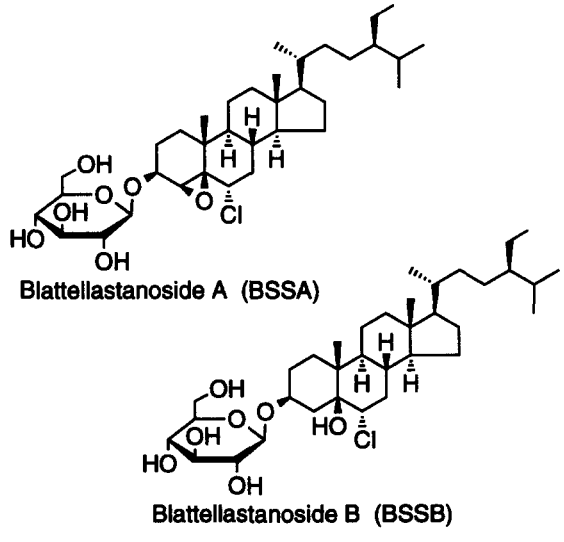
Key words: Aggregation, blattellastanoside A, German cockroach, pheromone chlorinated steroids, fluorinated steroids.

Results and Discussion

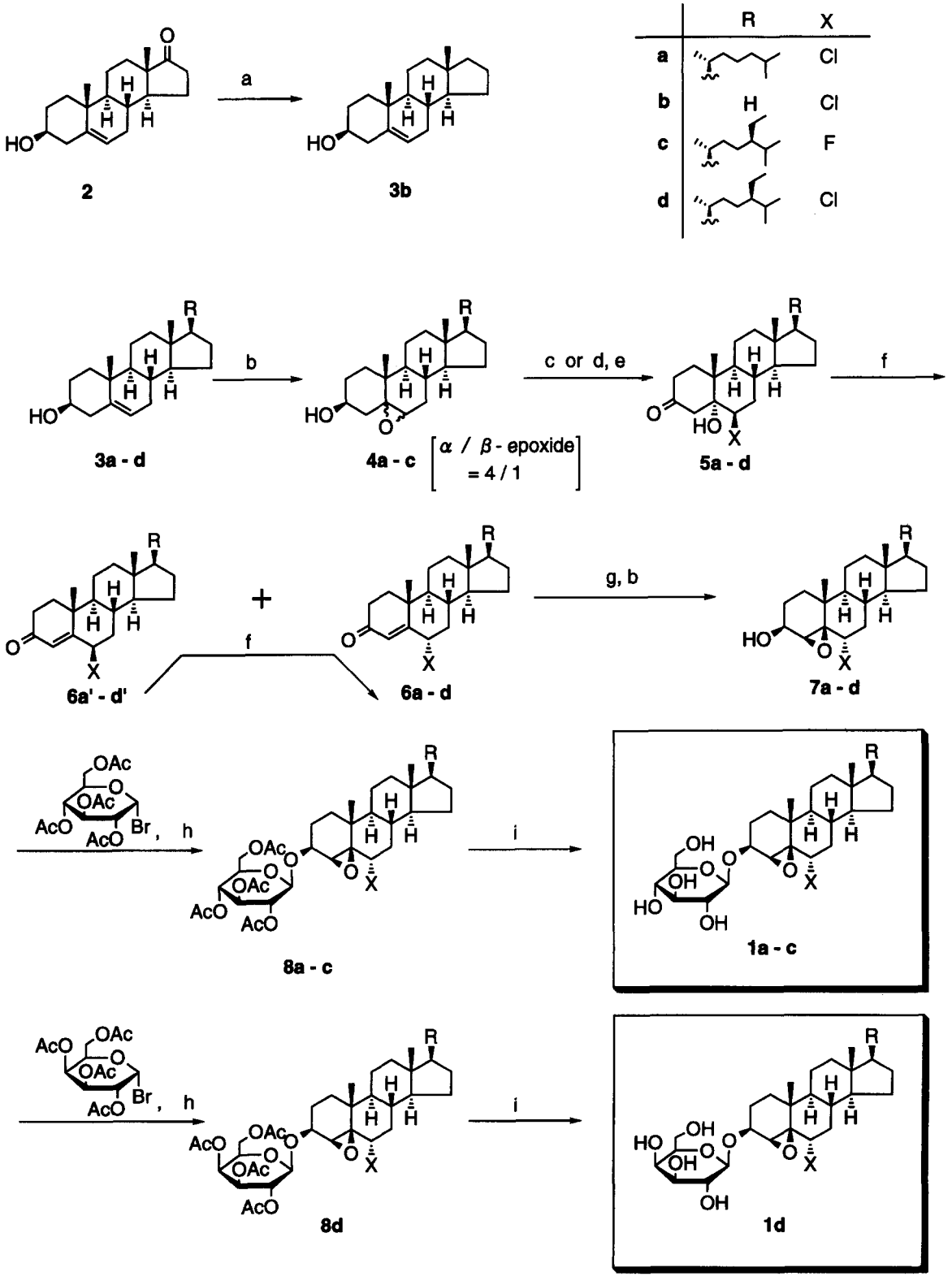
Preparation of the 5β-cholestane analogue 1a

Synthesis of the four analogues **1a–d** of blattellastanoside A is summarized in Scheme 2. We employed the route similar to that which was developed previously for the synthesis of blattellastanoside A itself.[7] Cholesterol (**3a**) was the starting material for the synthesis of the 5β-cholestane analogue **1a**. Epoxidation of **3a** with *m*-chloroperbenzoic acid (MCPBA) afforded the epoxide **4a** as a 4:1 mixture of the α- and β-epoxides.[8] Treatment of **4a** with hydrogen chloride was followed by chromic acid oxidation of the product to give chloro ketol **5a**. Dehydration of **5a** with concentrated hydro-



Scheme 1. Structures of blattellastanoside A and B.

chloric acid and anhydrous magnesium sulfate in chloroform yielded a mixture of the axial-chloro enone **6a'** and its equatorial isomer **6a**. The stereochemistry assigned to **6a** and **6a'** was on the basis of their ^1H NMR analysis concerning the signals due to the proton at C-6 (see Experimental). The mixture of **6a** and **6a'**



Scheme 2. Synthesis of the analogues of blattellastanoside A. Reagents: (a) $N_2H_4 \cdot H_2O$, KOH (98%); (b) MCPBA, CH_2Cl_2 (70–97%), (c) HCl, $CHCl_3$ for **4a**, **b** and **d**, (d) 46% HF, $BF_3 \cdot OEt_2$, $MgSO_4$, C_6H_6/Et_2O for **4c**; (e) Jones CrO_3, Me_2CO/CH_2Cl_2 (62–79%, 2 steps); (f) 37% HCl, $MgSO_4$, $CHCl_3$ (74–89% of **6a–d**); (g) $LiAl(OBut)_3H$, THF; (h) $Hg(CN)_2$, $C_6H_6/MeNO_2$ (68–76%); (i) NaOMe, MeOH/THF (51–92%).

could be separated by silica gel chromatography and the undesired axial-chloro enone **6a'** was equilibrated again under the above-mentioned acidic conditions to give more stable equatorial-chloro enone **6a** in 74% total yield. Reduction of **6a** with lithium tri(*tert*-butoxy)aluminum hydride generated a quasi-equatorial and β-oriented hydroxy group at C-3.[9] Epoxidation of the resulting allylic alcohol with MCPBA furnished the epoxy alcohol **7a**. Glucosidation of **7a** with aceto-bromo-D-glucose under the Königs–Knorr conditions gave **8a** as needles, which was deacetylated to give the 5β-cholestane analogue **1a**, mp 156–158 °C, as fine prisms. The overall yield of **1a** based on cholesterol (**3a**) was 24% (eight steps).

Preparation of the 5β-androstane analogue 1b

Synthesis of the analogue **1b** without the steroid side chain started from commercially available 3β-hydroxy-5-androsten-17-one (**2**), which was reduced under the Wolff–Kishner conditions to give 5-androsten-3β-ol (**3b**).[10,11] This was submitted to the same sequence of the reactions as in the case of **1a** to give **1b** via **4b**, **5b**, **6b**, **7b** and **8b**. The final product **1b**, mp 219–220 °C, was obtained in 25% overall yield based on **2** (nine steps).

Preparation of the fluoro analogue 1c

Introduction of the fluorine substituent at C-6 was achieved by treatment of the epoxide **4c** with fluorinating reagents to effect the cleavage of the epoxy ring. We examined four different conditions: (i) pyridine hydrofluoride in dichloromethane, (ii) hydrofluoric acid and magnesium sulfate in dichloromethane, (iii) boron trifluoride etherate in dichloromethane and (iv) hydrofluoric acid, boron trifluoride etherate and magnesium sulfate in benzene–ether.[12] The yields of **5c** realized under these conditions followed by oxidation were (i) 42, (ii) 29, (iii) 15 and (iv) 62%. We therefore prepared the fluoro ketol (**5c**) under the condition (iv) followed by oxidation. In the ^{1}H NMR spectrum of **5c**, the signal due to the proton at C-6 appeared at $\delta = 4.23$ (br dt, $J = 48.0$ and 2.4 Hz) to reveal the β- and axial orientation of the fluorine substituent. Dehydration with concomitant epimerization at C-6 of **5c** took place smoothly by treatment with hydrochloric acid to give **6c** in 89% yield without any halogen exchange at C-6. Conversion of **6c** to the target molecule **1c**, mp 181–182 °C, was executed via **7c** and **8c**. The overall yield of **1c** was 27% based on **3c** (eight steps).

Preparation of the galactoside analogue 1d

The known aglycone **7d**[7] was galactosylated with aceto-bromo-D-galactose[13] under the Königs–Knorr conditions in the presence of mercury(II) cyanide to give **8d**. Deacetylation of **8d** furnished the galactoside analogue **1d**, mp 127–128 °C, in 12% overall yield based on **3d** (eight steps).

Preliminary results of bioassay

The bioassay of the analogues **1a–d** as well as the aglycones of blattellastanoside A and B was carried against the German cockroaches at Kyoto University and details will be reported by one of us (M.S.) in due course. Results so far obtained (Scheme 3) showed that the fluoro analogue **1c** was more active than blattellastanoside A, while **1a** was only slightly less active than blattellastanoside A. The analogues **1b** and **1d** as well as the aglycones of blattellastanoside A and B were inactive. We therefore conclude that (i) the steroidal side chain is required for the bioactivity and (ii) the sugar part of the pheromone is necessary and cannot be replaced by D-galactose. The former situation is similar to what we have observed in the case of the steroidal plant growth hormone brassinolide (Scheme 3).[14] A brassinolide analogue without the steroidal side chain was biologically inactive.[14] The side-chain part of the steroidal bioregulators seems to play an important role in expressing the biological activities.

In conclusion, through the synthesis and bioassay of the analogues **1a–d** of blattellastanoside A, we were able to clarify the structure–activity relationship as summarized in Scheme 3.

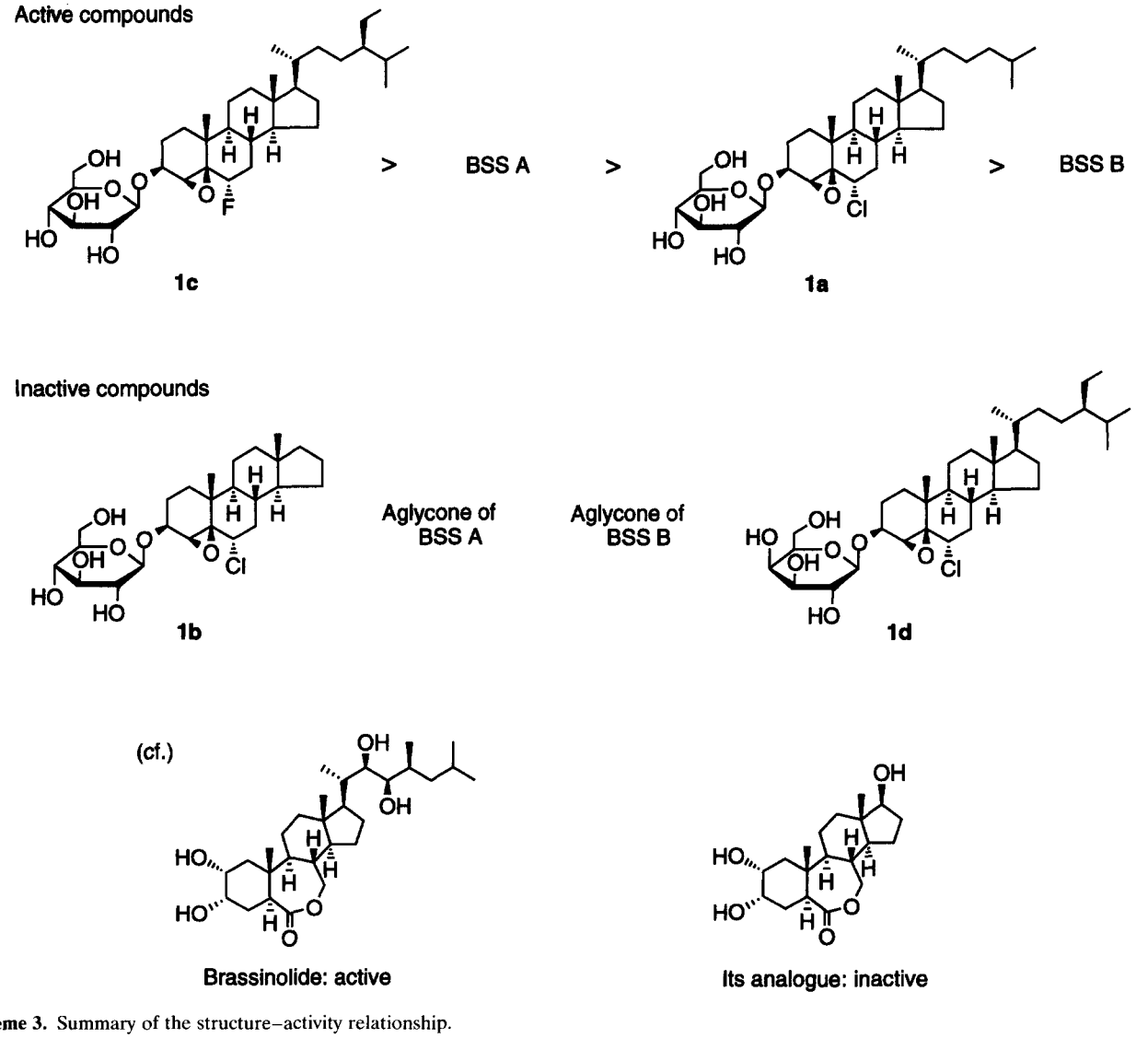
Experimental

All mps are uncorrected and measured on a Yanagimoto micromelting point apparatus. IR spectra were measured on a Jasco A 102 spectrometer. ^{1}H NMR spectra were recorded in $CDCl_3$ with TMS as an internal standard at 300 MHz on a Bruker AC-300 spectrometer. ^{13}C NMR spectra were recorded with $CDCl_3$ as an internal standard at 75 MHz on a Bruker AC-300 spectrometer. Optical rotations were measured on a Jasco DIP-371 polarimeter. Column chromatography was carried out on columns packed with Merck Kieselgel 60, Art. no. 7734.

5-Androsten-3β-ol (3b). 3β-Hydroxy-5-androsten-17-one (**2**) (13.0 g, 45.0 mmol), potassium hydroxide (23.6 g, 0.42 mol) and hydrazine hydrate (44.0 mL, 0.88 mol) were added into diethylene glycol (400 mL). The mixture was heated at 120 °C for 1 h. The bath temperature was then raised to 230 °C to remove excess hydrazine and water. The mixture was heated at 230 °C for 3.5 h, cooled and poured into water (2 L). The precipitated crude **3b** was collected on a filter, washed with water, dried and recrystallized from acetone to give **3b** (11.1 g, 98%); mp 134–135 °C (cf. ref 11 132–135 °C); $[\alpha]_D^{23} -68.3°$ (*c* 1.00, EtOH) {cf. ref 11 $[\alpha]_D^{23} -47°$ (EtOH)}. IR (KBr): ν 3280 (s, OH), 1050 cm^{-1} (s, C—O). ^{1}H NMR: δ 0.72 (s, 3H, 18-H), 1.02 (s, 3H, 19-H), 2.01 (ddt, 1H, $J = 15.6$, 5.3, 2.4 Hz), 2.17–2.35 (m, 2H), 3.47–3.59 (m, 1H, 3-H), 5.33–5.40 (m, 1H, 6-H). ^{13}C NMR: δ 17.4, 19.6, 20.7, 21.3, 25.8, 31.9, 32.36, 32.38, 36.8, 37.5, 38.9, 40.5, 40.8, 42.5, 50.7, 55.1, 72.0, 121.9, 141.0. Found: C, 82.74; H, 11.08. Calcd for $C_{19}H_{30}O$: C, 83.15; H, 11.02.

A mixture of 5α,6α- and 5β,6β-epoxycholestan-3β-ol (4a). A solution of MCPBA (55% purity, 37.6 g, 120 mmol) in dichloromethane (400 mL) was added dropwise to a stirred and ice-cooled solution of cholesterol **3a** (38.6 g, 100 mmol) in dichloromethane (600 mL). The mixture was stirred for 1 h at room temperature. It was then washed with 10% sodium hydrogen sulfite solution, 5% sodium thiosulfate solution, saturated sodium hydrogen carbonate solution and brine, dried over anhydrous magnesium sulfate, and concentrated in vacuo. The residue was chromatographed over silica gel (400 g). Elution with *n*-hexane: ethyl acetate (5:1→3:1) yielded **4a** (39.1 g, 97%) as an amorphous solid. IR (KBr): ν 3350 (s, OH), 1063 (m, C—O), 1040 cm^{-1} (m). ^1H NMR: δ 0.61 (major) and 0.64 (minor, each s, total 3H, 18-H), 0.85 (d, 3H, $J = 6.9$ Hz, 26-H), 0.86 (d, 3H, $J = 6.9$ Hz, 27-H), 0.88 (d, 3H, $J = 7.3$ Hz, 21-H), 0.99 (minor) and 1.06 (major, each s, total 3H, 19-H), 2.89 (major, d, $J = 3.3$ Hz) and 3.05 (minor, d, $J = 2.2$ Hz) (total 1H, 6-H), 3.65–3.75 (minor) and 3.85–3.97 (major, each m, total 1H, 3-H). ^{13}C NMR: δ 12.0, 16.0, 18.8, 20.8, 22.7, 23.0, 24.0, 24.2, 28.1, 28.2, 29.0, 30.1, 31.3, 32.6, 35.0, 35.9, 36.3, 39.7, 40.0, 42.5, 42.7, 56.1, 56.4, 57.0, 59.5, 65.9, 68.9. This was employed in the next step without further purification.

A mixture of 5α,6α- and 5β,6β-epoxyandrostan-3β-ol (4b). In the same manner as described above, **3b** (10.5 g, 38.3 mmol) was converted to a mixture of 5α,6α- and 5β,6β-epoxyandrostan-3β-ol (**4b**) (10.7 g, 97%) as an amorphous solid by treatment with MCPBA (55% purity, 13.2 g, 42.1 mmol). IR (KBr): ν 3450 (s, OH), 1060 (s, C—O), 1035 cm^{-1} (s, C—O). ^1H NMR: δ 0.65 (major) and 0.68 (minor, each s, total 3H, 18-H), 1.00 (minor) and 1.07 (major, each s, total 3H, 19-H), 2.07 (dd, 1H, $J = 12.5$, 11.5 Hz), 2.90 (major, d, $J = 4.3$ Hz) and 3.06 (minor, d, $J = 2.4$ Hz, total 1H, 6H), 3.64–3.76 (minor) and 3.85–3.97 (major, each m, total 1H, 3-H). ^{13}C NMR: δ 16.1, 17.2, 17.3, 17.4, 20.5, 20.6, 20.9, 22.2, 25.5, 25.7, 29.3, 30.2, 30.4, 31.2, 31.3, 32.7, 33.1, 35.1, 35.2, 37.4, 38.5, 38.9, 40.1, 40.2, 40.5, 40.70, 40.73, 42.4, 43.1, 51.8, 54.5, 55.2, 59.4,



Scheme 3. Summary of the structure–activity relationship.

63.1, 63.8, 65.8, 68.8, 69.5. This was employed in the next step without further purification.

6β-Chloro-5-hydroxy-5α-cholestan-3-one (5a). Into an ice-cooled and stirred solution of **4a** (25.0 g, 62.1 mmol) in chloroform (670 mL) was bubbled dry hydrogen chloride until saturation. After stirring for 1 h, the reaction mixture was concentrated under reduced pressure and then the residue was dissolved in acetone:dichloromethane (2:1, 600 mL). Jones reagent (2.67 M, 47 mL) was added slowly to the ice-cooled solution and the reaction mixture was stirred at the same temperature for 1 h. 2-Propanol (25 mL) was added to the reaction mixture and the mixture was stirred for 30 min The solvent was evaporated to about a half volume at room temperature. The residue was poured into water (1 L) and then precipitated crude **5a** was collected on a filter by filtration. The crude product was washed with water, dried and then washed with *n*-hexane. Recrystallization of the crude product from ethanol gave **5a** as needles (19.5 g, 72%); mp 211–212 °C; $[\alpha]_D^{20}$ −3.63° (*c* 1.02, $CHCl_3$) IR (KBr): ν 3400 (s, OH), 1705 cm^{-1} (s, C=O). ^1H NMR: δ 0.74 (s, 3H, 18-H), 0.87 (d, 3H × 2, *J* = 6.6 Hz, 26-H and 27-H), 0.92 (3H, d, *J* = 6.6 Hz, 21-H), 1.45 (3H, s, 19-H), 2.18 (1H, br d, *J* = 15.5 Hz, 4-H), 2.30–2.50 (m, 2H), 3.35 (d, 1H, *J* = 15.5 Hz, 4-H), 3.84 (br s, 1H, 6-H). ^{13}C NMR: δ 12.3, 18.0, 18.9, 21.5, 22.7, 23.0, 24.0, 24.3, 28.2, 28.3, 30.2, 34.9, 35.6, 35.9, 36.3, 37.9, 39.7, 39.9, 42.9, 46.0, 50.8, 55.4, 56.4, 63.8, 78.9, 210.7 (3-C). Found: C, 73.96; H, 10.37. Calcd for $C_{27}H_{45}O_2Cl$: C, 74.19; H, 10.38.

6α-Chloro-5-hydroxy-5α-androstan-3-one (5b). In the same manner as mentioned above, treatment of **4b** (10.0 g, 34.4 mmol) with hydrogen chloride followed by Jones reagent gave **5b** (84.4 g, 79%) as needles; mp 170–171 °C; $[\alpha]_D^{23}$ −37.3° (*c* 0.985, $CHCl_3$). IR (KBr): ν 3390 (s, OH), 1710 cm^{-1} (s, C=O). ^1H NMR: δ 0.78 (s, 3H, 18-H), 0.98–1.10 (m, 1H), 1.10–1.32 (m, 3H), 1.46 (s, 3H, 19-H), 2.17 (dd, 1H, *J* = 15.3, 2.1 Hz, 4-H), 2.28–2.50 (m, 2H), 3.35 (d, 1H, *J* = 15.4, Hz, 4-H), 3.86 (dd, 1H, *J* = 3.6, 2.4 Hz, 6-H). ^{13}C NMR: δ 17.5, 17.8, 20.4, 21.3, 25.4, 30.3, 34.8, 35.7, 37.7, 38.6, 39.7, 40.3, 40.9, 46.1, 50.5, 53.3, 63.6, 78.7, 210.9 (3-C). Found: C, 70.03; H, 9.10. Calcd for $C_{19}H_{29}O_2Cl$: C, 70.24; H, 9.00.

6α-Fluoro-5-hydroxy-5α-stigmastan-3-one (5c). To an ice-cooled solution of **4c** (2.00 g, 4.67 mmol) in benzene:ether (1:1, 100 mL) were added boron trifluoride–etherate (1.7 mL, 14.0 mmol), anhydrous magnesium sulfate (2.0 g) and hydrofluoric acid (46%, 0.5 mL, 9.34 mmol), successively. After stirring for 30 min at the same temperature, water was added to the reaction mixture. The organic layer was separated, washed with saturated sodium hydrogen carbonate, water and brine, and then dried over anhydrous magnesium sulfate. The oxidation of the crude product with Jones reagent as described above gave the desired product **5c** (1.29 g, 62%) as plates; mp 254–255 °C; $[\alpha]_D^{23}$ +10.1° (*c* 0.209, $CHCl_3$). IR (KBr): ν 3280 (s, OH), 1710 cm^{-1} (s, C=O). ^1H NMR: δ 0.71 (s, 3H, 18-H), 0.82 (d, 3H, *J* = 6.6 Hz, 26-H), 0.84 (d, 3H, *J* = 6.6 Hz, 27-H), 0.85 (t, 3H, *J* = 6.8 Hz, 29-H), 0.92 (d, 3H. *J* = 6.4 Hz, 21-H), 1.28 (d, 3H, *J* = 3.7 Hz, 19-H), 1.98–2.07 (m, 1H), 2.12 (dd, 1H, *J* = 15.6, 1.7 Hz, 4-H), 2.31–2.53 (m, 2H), 3.16 (dd, 1H, *J* = 15.6, 2.6 Hz, 4-H), 4.23 (br dt, 1H. *J* = 48.0, 2.4 Hz, 6-H). ^{13}C NMR: δ 12.1, 15.6, 15.7, 18.9, 19.2, 20.0, 21.4, 23.2, 24.2, 26.3, 28.4, 29.3, 30.4, 31.9, 32.2, 33.5, 34.1, 36.3, 38.0, 38.8, 39.9, 42.9, 45.5, 46.0, 49.1, 55.9, 56.3, 95.2 (d, *J* = 179 Hz, 6-C), 211.1 (3-C). Found: C, 77.41; H, 11.05. Calcd for $C_{29}H_{49}O_2F$: C, 77.62; H, 11.01.

6α-Chlorocholest-4-en-3-one (6a). To a solution of **5a** (5.00 g, 11.4 mmol) in chloroform (500 mL) was added concentrated hydrochloric acid (5.9 mL, 57 mmol) in the presence of anhydrous magnesium sulfate (12.0 g) and then the mixture was stirred for 1.5 h at room temperature. After filtraton of the mixture, the filtrate was washed with water, 10% sodium hydrogen carbonate and brine, and dried over anhydrous magnesium sulfate. The solvent was removed and the residue was chromatographed over silica gel (150 g), eluting with *n*-hexane:ethyl acetate (30:1→20:1). Further purification by recrystallization from diisopropyl ether gave pure **6a** (2.44 g) as needles and a mixture of **6a** and **6a′** (2.28 g). Treatment of the mixture in the same procedure as described above gave an additional amount of **6a** (1.13 g). The total yield of **6a** was 3.57 g (74%); mp 124–125 °C, $[\alpha]_D^{23}$ +65.2° (*c* 1.00, $CHCl_3$). IR (KBr): ν 1670 (s, C=O), 1615 cm^{-1} (s, C=C). ^1H NMR: δ 0.71 (s, 3H, 18-H), 0.86 (d, 3H, *J* = 6.6 Hz, 26-H), 0.87 (d, 3H, *J* = 6.8 Hz, 27-H), 0.91 (d, 3H, *J* = 6.5 Hz, 21-H), 1.21 (s, 3H, 19-H), 2.00–2.10 (m, 2H), 2.30–2.49 (m, 3H), 4.67 (ddd, 1H, *J* = 11.9, 5.1, 1.8 Hz, 6-H), 6.37 (d, 1H, *J* = 1.5 Hz, 4-H). ^{13}C NMR: δ 12.1, 18.4, 18.8, 21.2, 22.7, 22.9, 24.0, 24.2, 28.1, 28.2, 33.9, 35.9, 36.2, 36.4, 39.5, 39.6, 40.6, 42.7, 43.8, 53.4, 55.6, 56.2, 59.1, 123.7, 166.1, 199.2 (3-C). Found: C, 77.58; H, 10.40. Calcd for $C_{27}H_{43}OCl$: C, 77.38; H, 10.34. ^1H NMR data of **6a′** at H-6: δ 4.73 (dd, 1H, *J* = 2.9, 1.8 Hz).

6α-Chloroandrost-4-en-3-one (6b). In the same manner as mentioned above, **5b** (2.00 g, 6.15 mmol) was subjected to dehydration and repeated epimerization to give **6b** (1.41 g, 74%) as needles; mp 151–152 °C; $[\alpha]_D^{23}$ +61.0° (*c* 1.00, $CHCl_3$); IR (KBr): ν 1675 (s, C=O), 1615 cm^{-1} (m, C=C). ^1H NMR: δ 0.74 (s, 3H, 18-H), 1.20 (s, 3H, 19-H), 2.05 (dt, 1H, *J* = 13.4, 4.8 Hz), 2.30–2.49 (m, 3H), 4.67 (ddd, 1H, *J* = 12.8, 5.2, 1.8 Hz, 6-H), 6.36 (d, 1H, *J* = 1.8 Hz, 4-H). ^{13}C NMR: δ 17.5, 18.4, 20.5, 21.2, 25.4, 34.0, 36.4, 36.5, 38.3, 40.1, 40.7, 40.9, 44.1, 53.65, 53.68, 59.1, 123.7, 166.0, 199.1 (3-C). Found: C, 74.04; H, 8.94. Calcd for $C_{19}H_{27}OCl$: C, 74.36; H, 8.87.

6α-Fluorostigmast-4-en-3-one (6c). Under the same conditions as described above, **5c** (4.5 g, 10.0 mmol) gave **6c** (3.83 g, 89%) as plates; mp 107–108 °C; $[\alpha]_D^{23}$ +80.9° (*c* 1.00, $CHCl_3$). IR (KBr): ν 1685 (s, C=O), 1625 (m, C=C), 1060 cm^{-1} (m, C—O). ^1H NMR: δ 0.71 (s, 3H, 18-H), 0.82 (d, 3H, *J* = 6.5 Hz,

26-H), 0.84 (d, 3H, $J = 6.5$ Hz, 27-H), 0.85 (t, 3H, $J = 6.9$ Hz, 29-H), 0.92 (d, 3H, $J = 6.4$ Hz, 21-H), 1.18 (s, 3H, 19-H), 1.98–2.10 (m, 2H), 2.23–2.37 (m, 1H), 2.38–2.52 (m, 2H), 5.09 (dddd, 1H, $J = 48.0$, 12.2, 5.9, 1.7 Hz, 6-H), 6.08 (s, 1H, 4-H). ^{13}C NMR: δ 12.05, 12.13, 18.2, 18.8, 19.2, 20.0, 21.1, 23.3, 24.3, 26.3, 28.2, 29.4, 33.58, 33.72, 33.9, 34.0, 36.2, 36.4, 38.6, 38.8, 39.29, 39.33, 39.5, 42.6, 46.0, 53.7, 55.7, 56.1, 88.5 (d, $J = 185.1$ Hz, 6-C), 119.7 (d, $J = 14.6$ Hz), 166.4 (d, $J = 11.2$ Hz), 198.8 (3-C). Found: C, 81.00; H, 11.04. Calcd for $C_{29}H_{47}OF$: C, 80.87; H, 11.00.

6α-Chloro-4β,5-epoxy-5β-cholestan-3β-ol (7a). To an ice-cooled suspension of lithium tri(*tert*-butoxy)aluminum hydride (1.97 g, 7.75 mmol) in dry THF (100 mL) was added a solution of **6a** (2.50 g, 5.96 mmol) in THF (50 mL) with stirring. After stirring for 2.5 h, the excess hydride was decomposed with 1 N hydrochloric acid solution. The mixture was diluted with ethyl acetate (200 mL), washed with brine, dried over anhydrous magnesium sulfate and concentrated in vacuo. To the solution of the residue in dichloromethane (100 mL) was added a solution of MCPBA (55% purity, 2.06 g, 6.56 mmol) in dichloromethane (100 mL) with ice-cooling. After the reaction mixture was stirred for 6 h, the mixture was washed with 10% sodium sulfite solution, 5% sodium thiosulfate solution, 10% sodium hydrogen carbonate solution and brine. The organic layer was dried over anhydrous magnesium sulfate and concentrated in vacuo. The residue was chromatographed over silica gel (80 g), eluting with *n*-hexane:ethyl acetate (10:1→5:1), to give **7a** (1.85 g, 71%) as a syrup. For an analytical sample, a small amount of **7a** was further purified as follows: (i) Ac_2O, py, (ii), chromatography, (iii) NaOMe, MeOH, (iv) chromatography; $[\alpha]_D^{23} -19.9°$ (*c* 0.80, $CHCl_3$); IR (film): ν 3425 (s, O—H), 1030 cm^{-1} (m, C—O). ^{1}H NMR: δ 0.67 (s, 3H, 18-H), 0.86 (d, 3H × 2, $J = 6.6$ Hz, 26-H and 27-H), 0.90 (d, 3H, $J = 6.5$ Hz, 21-H), 1.05 (s, 3H, 19-H), 1.80–1.95 (m, 1H), 2.00 (br dt, 1H, $J = 12.7$, 3.0 Hz), 2.26 (dt, 1H, $J = 12.4$, 4.0 Hz), 3.80 (d, 1H, $J = 4.5$ Hz, 4-H), 4.10 (br s, 1H, 3-OH), 4.46 (dd, 1H, $J = 4.4$, 10.5 Hz, 6-H). ^{13}C NMR: δ 12.1, 18.8, 19.3, 21.5, 22.7, 22.9, 24.0, 24.3, 25.8, 26.7, 28.1, 28.2, 35.9, 36.0, 36.3, 38.6, 39.6, 41.9, 42.9, 46.7, 55.8, 56.3, 57.6, 58.3, 63.5, 69.0. Found: C, 73.95; H, 10.26. Calcd for $C_{27}H_{45}O_2Cl$: C, 74.19; H, 10.38.

6α-Chloro-4β,5-epoxy-5β-androstan-3β-ol (7b). In the same manner as mentioned above, **6b** (2.50 g, 8.14 mmol) was reduced with lithium tri(*tert*-butoxy)aluminum hydride (2.69 g, 10.58 mmol), followed by epoxidation with MCPBA (55% purity, 2.80 g, 8.90 mmol). The product was purified by chromatography and recrystallized from *n*-hexane to give **7b** (1.88 g, 71%) as plates; mp 121–122 °C; $[\alpha]_D^{23} -49.4°$ (*c* 1.06, $CHCl_3$); IR (KBr): ν 3270 (s, O—H), 1035 cm^{-1} (s, C—O). ^{1}H NMR: δ 0.72 (s, 3H, 18-H), 1.06 (s, 3H, 19-H), 2.29 (dt, 1H, $J = 12.2$, 4.3 Hz, 4-H), 3.80 (d, 1H, $J = 4.5$ Hz, 3-H), 4.10 (br s, 1H, 3-OH), 4.47 (dd, 1H, $J = 12.9$, 4.4 Hz, 6-H). ^{13}C NMR: δ 17.5, 19.3, 20.5, 21.5, 25.5, 25.7, 26.8, 36.3, 38.5, 38.7, 40.3, 41.1, 42.1, 46.9, 53.9, 57.6, 58.2, 63.5, 69.0. Found: C, 70.27; H, 9.30. Calcd for $C_{19}H_{29}O_2Cl$: C, 70.24; H, 9.00.

4β,5-Epoxy-6α-fluoro-5β-stigmastan-3β-ol (7c). According to the method described above, **6c** (3.50 g, 8.14 mmol) was converted to **7c**. The crude product was chromatographed over silica gel (110 g), eluting with *n*-hexane:ethyl acetate (10:1→5:1), to give pure **7c** (2.91 g, 80%) as a syrup; $[\alpha]_D^{23} +9.86°$ (*c* 1.00, $CHCl_3$). IR (film); ν 3425 (s, O—H), 1050 cm^{-1} (s, C—O). ^{1}H NMR: δ 0.68 (s, 3H, 18-H), 0.81 (d, 3H, $J = 6.5$ Hz, 26-H), 0.83 (d, 3H, $J = 6.5$ Hz, 27-H), 0.84 (t, 3H, $J = 6.9$ Hz, 29-H), 0.91 (d, 3H, $J = 6.4$ Hz, 21-H), 1.01 (s, 3H, 19-H), 1.80–1.95 (m, 1H), 2.00 (br dt, 1H, $J = 12.6$, 2.9 Hz), 2.13–2.24 (m, 1H), 2.33 (d, 1H, $J = 9.5$ Hz), 3.63 (d, 1H, $J = 4.3$ Hz, 4-H), 4.06 (br q, 1H, $J = 3.9$ Hz, 3-OH), 4.79 (ddd, 1H, $J = 51.3$, 12.0, 5.3 Hz, 6-H). ^{13}C NMR: δ 12.0, 12.1. 18.8, 19.2, 19.3, 19.9, 21.5, 23.2, 24.4, 25.8, 26.3, 26.9, 28.2, 29.3, 33.5, 33.6, 34.0, 36.2, 36.9, 37.1, 37.4, 39.6, 42.8, 46.0, 47.0, 55.9, 56.2, 57.6, 57.8, 63.6, 69.3, 69.5, 87.0 (d, $J = 183.1$ Hz, 6-C). Found: C, 77.70; H, 11.09. Calcd for $C_{29}H_{49}O_2F$: C, 77.62; H, 11.00.

6α-Chloro-4β,5-epoxy-5β-cholestan-3β-yl 2,3,4,6-tetra-acetyl-β-D-glucopyranoside (8a). A solution of **7a** (1.50 g, 3.43 mmol) in dry benzene and dry nitromethane (1:1, 200 mL) was stirred and heated at 110 °C to remove moisture azeotropically. The mixture was concentrated to a volume of ca. 100 mL and then cooled under argon. To the solution was added tetra-*O*-acetyl-β-D-glucopyranosyl bromide (2.82 g, 6.82 mmol) and mercury(II) cyanide (1.73 g, 6.86 mmol), and the mixture was stirred for 1.5 h at 90 °C under argon. After cooling, the mixture was diluted with ethyl acetate (250 mL), washed with saturated sodium hydrogen carbonate solution and brine, dried over anhydrous magnesium sulfate and concentrated in vacuo. The residue was chromatographed over silica gel (80 g), eluting with *n*-hexane:ethyl acetate (10:→5:1), to give **8a** (1.87 g, 71%) as needles from methanol; mp 132–134 °C; $[\alpha]_D^{24} -30.6°$ (*c* 1.01, $CHCl_3$). IR (KBr): ν 1750 (s, C=O), 1220 (s, C—O), 1040 cm^{-1} (s, C—O). ^{1}H NMR; δ 0.67 (s, 3H, 18-H), 0.86 (d, 3H, $J = 6.6$ Hz, 26-H), 0.87 (d, 3H, $J = 6.6$ Hz, 27-H), 0.90 (d, 3H, $J = 6.6$ Hz, 21-H), 1.02 (s, 3H, 19-H), 1.77–1.93 (m, 1H), 2.01, 2.03, 2.09 and 2.10 (each s, 3H × 4, CH_3CO), 2.26 (dt, 1H, $J = 12.2$, 3.6 Hz), 3.70 (d, 1H, $J = 3.5$ Hz, 4-H), 3.74 (ddd, 1H, $J = 9.9$, 4.4, 2.4 Hz, 5′-H), 4.15 (dd, 1H, $J = 14.7$, 2.3 Hz, 6′-H), 4.21–4.28 (m, 1H, 3-H), 4.27 (dd, 1H, $J = 12.3$, 4.6 Hz, 6′-H), 4.43 (dd, 1H, $J = 12.9$, 4.3 Hz, 6-H), 4.83 (d, 1H, $J = 7.8$ Hz, 1′-H), 5.00 (dd, 1H, $J = 9.0$, 7.9 Hz, 2′-H), 5.09 (t, 1H, $J = 9.6$ Hz, 4′-H), 5.26 (t, 1H, $J = 9.5$ Hz, 3′-H). ^{13}C NMR: δ 12.1, 18.8, 18.9, 20.7, 20.9, 21.6, 22.7, 22.9, 23.5, 24.0, 24.3, 28.1, 28.2, 29.1, 35.9, 36.0, 36.3, 38.6, 39.6, 39.7, 42.0, 42.9, 47.9, 54.6, 55.8, 56.3, 58.7, 62.2, 66.9, 68.8, 70.6, 71.5, 72.1, 72.9, 98.9 (1′-C), 169.6, 169.9, 170.3, 170.8. Found: C, 63.89; H, 8.28. Calcd for $C_{41}H_{63}O_{11}Cl$: C, 64.17; H, 8.28.

6α-Chloro-4β,5-epoxy-5β-androstan-3β-yl 2,3,4,6-tetra-acetyl-β-D-glucopyranoside (8b). In the same manner as mentioned above, **7b** (0.80 g, 2.46 mmol) was treated with tetra-*O*-acetyl-β-D-glucopyranosyl bromide (2.02 g, 4.92 mmol) and mercury(II) cyanide (1.21 g, 4.92 mmol) to give **8b** (1.10 g, 68%) as plates; mp 195–197 °C; $[\alpha]_D^{23}$ −50.4° (*c* 1.00, $CHCl_3$). IR (KBr): ν 1750 (s, C=O), 1220 (s, C—O), 1040 cm^{-1} (s, C—O). ^1H NMR: δ 0.72 (s, 3H, 18-H), 1.03 (s, 3H, 19-H), 2.01, 2.02, 2.09 and 2.10 (each s, 3H × 4, CH_3CO), 2.29 (dt, 1H, *J* = 12.2, 4.0 Hz), 3.70 (d, 1H, *J* = 3.5 Hz, 4-H), 3.75 (ddd, 1H, *J* = 10.1, 4.5, 2.5 Hz, 5′-H), 4.16 (dd, 1H, *J* = 12.2, 2.3 Hz, 6′-H), 4.21–4.27 (m, 1H, 3-H), 4.28 (dd, 1H, *J* = 13.1, 4.5 Hz, 6′-H), 4.44 (dd, 1H, *J* = 12.8, 4.3 Hz, 6-H), 4.84 (d, 1H, *J* = 8.0 Hz, 1′-H), 5.00 (dd, 1H, *J* = 9.6, 8.0 Hz, 2′-H), 5.09 (t, 1H, *J* = 9.6 Hz, 4′-H), 5.27 (t, 1H, *J* = 9.4 Hz, 3′-H). ^{13}C NMR: δ 17.5, 19.0, 20.5, 20.8, 20.9, 21.5, 23.5, 25.6, 29.0, 36.3, 38.5, 38.8, 40.3, 41.1, 42.3, 48.0, 53.9, 54.5, 58.6, 62.2, 66.8, 68.7, 70.5, 71.4, 72.1, 72.9, 98.8 (1′-C), 169.6, 170.0, 170.3, 170.8. Found: C, 60.54; H, 7.28. Calcd for $C_{33}H_{47}O_{11}Cl$: C, 60.49; H, 7.23.

4β,5-Epoxy-6α-fluoro-5β-stigmastan-3β-yl 2,3,4,6-tetra-acetyl-β-D-glucopyranoside (8c). According to the same method as described above, **7c** (1.68 g, 3.74 mmol) was glycosylated with tetra-*O*-acetyl-β-D-gluco-pyranosyl bromide (3.07 g, 7.48 mmol) and mercury(II) cyanide (1.88 g, 7.48 mmol) to give **8c** (2.21 g, 68%) as needles; mp 141–142 °C; $[\alpha]_D^{23}$ −16.8° (*c* 1.00, $CHCl_3$). IR (KBr): ν 1755 (s, C=O), 1230 (s, C—O), 1065 (s, C—O), 1040 cm^{-1} (s, C—O). ^1H NMR: δ 0.68 (s, 3H, 18-H), 0.81 (d, 3H, *J* = 6.6 Hz, 26-H), 0.84 (d, 3H, *J* = 6.7 Hz, 27-H), 0.85 (t, 3H, *J* = 6.9 Hz, 29-H), 0.91 (d, 3H, *J* = 6.2 Hz, 21-H), 1.00 (s, 3H, 19-H), 1.96–2.05 (m, 1H), 2.00, 2.03, 2.09 and 2.10 (each s, 3H × 4, CH_3CO), 2.15–2.25 (m, 1H), 3.58 (d, 1H, *J* = 3.1 Hz, 4-H), 3.70–3.79 (m, 1H, 5′-H), 4.15 (br dd, 1H, *J* = 12.2, 1.6 Hz, 6′-H), 4.19–4.27 (m, 1H, 3-H), 4.27 (dd, 1H, *J* = 12.3, 4.7 Hz, 6′-H), 4.76 (ddd, 1H, *J* = 50.6, 12.3, 5.2 Hz, 6-H), 4.84 (d, 1H, *J* = 8.1 Hz, 1′-H), 5.00 (dd, 1H, *J* = 9.3, 8.2 Hz, 2′-H), 5.09 (t, 1H, *J* = 9.6 Hz, 4′-H), 5.25 (t, 1H, *J* = 9.5 Hz, 3′-H). ^{13}C NMR: δ 12.0, 12.1, 18.8, 19.0, 19.1, 19.9, 20.8, 20.9, 21.5, 23.1, 23.4, 24.4, 26.1, 28.2, 29.0, 29.2, 33.3, 33.5, 33.9, 36.2, 36.8, 37.1, 37.2, 37.27, 37.31, 39.6, 42.7, 45.9, 48.1, 54.4, 54.6, 55.8, 56.1, 62.1, 67.3, 67.4, 68.6, 70.5, 71.3, 72.0, 72.8, 87.3 (d, *J* = 182.9 Hz, 6-C), 98.6 (1′-C), 169.6, 169.9, 170.3, 170.9. Found: C, 66.42; H, 8.61. Calcd for $C_{43}H_{67}O_{11}F$: C, 66.30; H, 8.67.

6α-Chloro-4β,5-epoxy-5β-stigmastan-3β-yl 2,3,4,6-tetra-acetyl-β-D-galactopyranoside (8d). In the same manner as mentioned above, **7d** (1.35 g, 2.91 mmol) was treated with tetra-*O*-acetyl-β-D-galactopyranosyl bromide[13] (2.31 g, 5.81 mmol) and mercury(II) cyanide (1.47 g, 5.81 mmol) to afford **8d** (1.76 g, 76%) as an amorphous solid; mp 94–95 °C; $[\alpha]_D^{22}$ −13.3° (*c* 1.00, $CHCl_3$). IR (KBr): ν 1750 (s, C=O), 1220 (s, C—O), 1070 cm^{-1} (s, C—O). ^1H NMR: δ 0.68 (s, 3H, 18-H), 0.81 (d, 3H, *J* = 6.6 Hz, 26-H), 0.83 (d, 3H, *J* = 6.6 Hz, 27-H), 0.84 (t, 3H, *J* = 6.9 Hz, 29-H), 0.90 (d, 3H, *J* = 6.4 Hz, 21-H), 1.02 (s, 3H, 19-H), 1.81–1.93 (m, 1H), 1.99, 2.06, 2.12 and 2.15 (each s, 3H × 4, CH_3CO), 2.26 (dt, 1H, *J* = 12.3, 3.8 Hz), 3.70 (d, 1H, *J* = 3.6 Hz, 4-H), 3.85 (dd, 1H, *J* = 6.5 Hz), 4.17 (dd, 2H, *J* = 6.6, 4.8 Hz), 4.25 (d, 1H, *J* = 3.7 Hz, 3-H), 4.44 (dd, 1H, *J* = 12.9, 4.4 Hz, 6-H), 4.80 (d, 1H, *J* = 7.7 Hz, 1′-H), 5.08 (dd, 1H, *J* = 10.7, 3.4 Hz), 5.21 (dd, 1H, *J* = 10.5, 7.8 Hz), 5.41 (d, 1H, *J* = 2.9 Hz). ^{13}C NMR: δ 12.0, 12.1, 18.8, 19.0, 19.1, 19.9, 20.8, 21.0, 21.5, 23.2, 23.5, 24.3, 26.3, 28.2, 28.8, 29.3, 34.0, 36.0, 36.2, 38.6, 39.6, 42.0, 42.8, 46.0, 47.7, 54.4, 55.8, 56.2, 58.6, 61.5, 66.8, 67.3, 69.0, 70.4, 71.0, 99.3 (1′-C), 170.1, 170.2, 170.4, 170.5. Found: C, 64.90; H, 8.54. Calcd for $C_{43}H_{67}O_{11}Cl$: C, 64.93; H, 8.49.

6α-Chloro-4β,5-epoxy-5β-cholestan-3β-yl β-D-glucopyra-noside (1a). To a solution of **8a** (0.77 g, 1.00 mmol) in methanol:THF (1:1, 80 mL) was added 28% sodium methoxide in methanol solution (0.96 mL, 5.00 mmol). The mixture was stirred for 1 h at room temperature and then neutralized with 10% aqueous citric acid (9.7 mL) with ice-cooling. The reaction mixture was concentrated under reduced pressure at room temperature. The residue was extracted thoroughly with chloroform and washed with water and brine. The extract was dried with anhydrous magnesium sulfate and concentrated in vacuo. The residue was chromatographed over silica gel (30 g). Elution with chloroform:methanol (20:1) gave **1a** (0.55 g, 92%) as fine prisms after recrystallization from 95% ethanol; mp 156–158 °C; $[\alpha]_D^{27}$ −26.6° (*c* 1.00, EtOH). IR (KBr): ν 3400 (s, O—H), 1070 (s, C—O), 1020 cm^{-1} (s, C—O). ^1H NMR: δ 0.67 (s, 3H, 18-H), 0.86 (d, 3H, *J* = 7.2 Hz, 26-H), 0.87 (d, *J* = 7.2 Hz, 27-H), 0.90 (d, 3H, *J* = 6.5 Hz, 21-H), 1.04 (s, 3H, 19-H), 1.80–1.95 (br, 1H), 2.00 (br d, 1H, *J* = 12.4 Hz), 2.24 (br dd, 1H, *J* = 12.0, 3.0 Hz), 3.37–3.51 (br, 2H, 2′-H and 5′-H), 3.55–3.68 (m, 2H, 3′-H and 4′-H), 3.82 (d, 1H, *J* = 3.3 Hz, 4-H), 3.83–3.95 (m, 2H, 6′-H), 4.24 (br s, 3H, 3-H), 4.43 (dd, 1H, *J* = 12.3, 4.2 Hz, 6-H), 4.60 (d, 1H, *J* = 7.5 Hz, 1′-H). ^{13}C NMR: δ 12.1, 18.8, 21.6, 22.7, 22.9, 23.7, 24.1, 24.3, 28.1, 28.3, 30.6, 35.9, 36.0, 36.3, 38.4, 39.6, 41.8, 42.8, 48.6, 55.7, 56.4, 56.5, 58.8, 62.1, 67.6, 70.0, 72.5, 73.7, 75.9, 76.5, 102.0 (1′-C). Found: C, 65.27; H, 9.43. Calcd for $C_{33}H_{55}O_7Cl \cdot H_2O$: C, 64.84; H, 9.40.

6α-Chloro-4β,5-epoxy-5β-androstan-3β-yl β-D-glucopyr-anoside (1b). In the same manner as described above, deprotection of **8b** (0.80 g, 1.22 mmol) with 28% sodium methoxide in methanol solution (1.17 mL, 6.10 mmol) in methanol:THF (1:1, 100 mL) gave **1b** (0.47 g, 90%) as an amorphous solid; mp 219–220 °C; $[\alpha]_D^{20}$ −58.9° (*c* 1.04, EtOH). IR (KBr): ν 3450 (s, O—H), 1065 (s, C—O), 1010 cm^{-1} (s, C—O). ^1H NMR: δ 0.71 (s, 3H, 18-H), 1.05 (s, 3H, 19-H), 2.26 (br dt, 1H, *J* = 12.5, 3.7 Hz), 3.43 (br s, 2H, 2′-H and 5′-H), 3.61 (br, 2H, 3′-H and 4′-H), 3.82 (d, 1H, *J* = 3.4 Hz, 4-H), 3.83–3.95 (m, 2H, 6′-H), 4.25 (br s, 1H, 3-H), 4.44 (dd, 1H, *J* = 12.0, 3.0, Hz, 6-H), 4.60 (d, 1H, *J* = 7.5 Hz, 1′-H). ^{13}C NMR: δ 17.5, 18.9, 20.6, 21.6, 23.7, 25.6, 30.2, 36.3, 38.6, 40.3, 41.1, 42.2, 48.7, 53.9,

56.2, 58.6, 62.2, 67.7, 70.1, 72.2, 73.8, 75.9, 76.5, 102.0 (1′-C). Found: C, 61.22; H, 8.09. Calcd for $C_{25}H_{39}O_7Cl$: C, 61.65; H, 8.07.

4β,5-Epoxy-6α-fluoro-5β-stigmastan-3β-yl β-D-glucopyranoside (1c). In the same manner as mentioned above, methanolysis of **8c** (0.97 g, 1.24 mmol) with 28% sodium methoxide in methanol solution (1.17 mL, 6.10 mmol) in methanol:THF (1:1, 100 mL) gave **1c** (0.51 g, 67%) as an amorphous solid; mp 181–182 °C; $[\alpha]_D^{23}$ −11.8° (*c* 1.00, EtOH). IR (KBr): ν 3425 (s, O—H), 1070 (s, C—O), 1050 cm^{-1} (s, C—O). ^1H NMR: δ 0.67 (s, 3H, 18-H), 0.81 (d, 3H, *J* = 6.5 Hz, 26-H), 0.82 (d, 3H, *J* = 6.5 Hz, 27-H), 0.84 (t, 3H, *J* = 7.1 Hz, 29-H), 0.91 (d, 3H, *J* = 6.2 Hz, 21-H), 1.00 (s, 3H, 19-H), 1.80–1.95 (br, 1H), 2.00 (br d, 1H, *J* = 12.0 Hz), 2.10–2.21 (br, 1H), 3.35–3.50 (m, 2H, 2′-H and 5′-H), 3.60 (br d, 2H, *J* = 7.5 Hz, 3′-H and 4′-H), 3.69 (d, 1H, *J* = 2.4 Hz, 4-H), 3.86 (br s, 2H, 6′-H), 4.19 (br s, 1H, 3-H), 4.60 (d, 1H, *J* = 7.5 Hz, 1′-H), 4.75 (ddd, 1H, *J* = 50.9, 12.0, 3.0 Hz, 6-H). ^{13}C NMR: δ 12.0, 12.1, 18.6, 18.8, 19.1, 20.0, 21.5, 23.2, 23.6, 24.4, 26.3, 28.2, 29.2, 31.6, 33.3, 33.4, 34.0, 36.3, 36.7, 36.9, 39.7, 42.7, 45.9, 49.6, 55.7, 56.3, 56.4, 56.6, 62.0, 68.0, 68.2, 69.9, 72.8, 73.6, 75.8, 76.4, 87.4 (d, *J* = 184.0 Hz, C-6), 101.8 (C-1′). Found: C, 68.48; H, 9.75. Calcd for $C_{35}H_{59}O_7F$: C, 68.81; H, 9.73.

6α-Chloro-4β,5-epoxy-5β-stigmastan-3β-yl β-D-galactopyranoside (1d). In the same manner as described above, treatment of **8d** (1.00 g, 1.26 mmol) with 28% sodium methoxide in methanol solution (1.22 mL, 6.30 mmol) in ice-cooled methanol:THF (1:1, 100 mL) gave **1d** (0.40 g, 51%) as an amorphous solid; mp 127–129 °C; $[\alpha]_D^{23}$ −20.9° (*c* 1.00, EtOH). IR (KBr): ν 3375 (s, O—H), 1060 cm^{-1} (s, C—O). ^1H NMR: δ 0.67 (s, 3H, 18-H), 0.81 (d, 3H, *J* = 6.6 Hz, 26-H), 0.84 (d, 3H, *J* = 6.6 Hz, 27-H), 0.85 (t, 3H, *J* = 6.9 Hz, 29-H), 0.90 (d, 3H, *J* = 6.3 Hz, 21-H), 1.05 (s, 3H, 19-H), 1.80–1.95 (br, 1H), 2.00 (br d, 1H, *J* = 12.5 Hz), 2.18–2.32 (m, 1H), 3.61 (t, 1H, *J* = 6.0 Hz), 3.69 (s, 2H), 3.82 (d, 1H, *J* = 3.5 Hz, 4-H), 3.85–4.00 (m, 2H), 4.04 (s, 1H, 3-H), 4.27 (br s, 1H), 4.44 (dd, 1H, *J* = 12.0, 4.0 Hz, 6-H), 4.51–4.60 (m, 1H, 1′-H). ^{13}C NMR: δ 12.0, 12.1, 18.8, 19.1, 20.0, 21.5, 23.2, 23.6, 24.3, 26.3, 28.3, 29.2, 30.5, 34.0, 35.9, 36.3, 38.4, 39.6, 41.8, 42.8, 45.9, 48.5, 55.6, 56.2, 56.4, 58.8, 61.5, 67.6, 68.8, 71.4, 72.4, 73.6, 74.7, 102.6 (1′-C). Found: C, 65.66; H, 9.37. Calcd for $C_{35}H_{59}O_7Cl$: C, 67.01; H, 9.48. Due to the hygroscopic nature of **1d**, a correct combustion analytical data could not be obtained.

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