Synthesis of Biological Markers in Fossil Fuels. 7.[1] Selected Diastereomers of 4α-Methyl-5α-stigmastane and 5α-Dinosterane

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Efficient routes for the preparation of selected C-23 and C-24 diastereomers of the C_{30} biological markers 4α-methyl-5α-stigmastane (1) and 5α-dinosterane (2) involved the alkylation of 20-(iodomethyl)-4α-methyl-5α-pregnane with either saturated or α,β-unsaturated esters. The alkylation of (20*S*)-20-(iodomethyl)-4α-methyl-5α-pregnane with methyl (3*R*)-3-ethyl-4-methylpentanoate furnished methyl (20*R*,23ζ,24*S*)-4α-methyl-5α-stigmastane-23-carboxylate, and a subsequent decarbomethoxylation provided (20*R*,24*R*)-1. The alkylation of (20*S*)-20-(iodomethyl)-4α-methyl-5α-pregnane with methyl (3*S*)-3,4-dimethylpentanoate led to methyl (20*R*,23ζ,24*R*)-4α,24-dimethyl-5α-cholestane-23-carboxylate, and the reduction of this mixture provided principally (20*R*,23*S*,24*R*)-5α-dinosteran-29-ol. The further reduction of the mesylate of this isomer secured (20*R*,23*S*,24*R*)-5α-dinosterane (**2a**). The application of the same sequence of reactions using methyl (3*R*)-3,4-dimethylpentanoate led principally to (20*R*,23*R*,24*S*)-5α-dinosterane (**2d**). The alkylation of (20*S*)-20-(iodomethyl)-4α-methyl-5α-pregnane with methyl (2ζ)-3,4-dimethyl-2-pentanoate and a subsequent reduction of the ester provided a separable mixture of (20*R*,23*R*)- and (20*R*,23*S*)-5α-dinoster-24-(28)-en-29-ol in a 2.4:1 ratio. The conversion of (20*R*,23*R*)-5α-dinoster-24(28)-en-29-ol to the corresponding *tert*-butyldimethylsilyl ether, reduction of the $\Delta^{24(28)}$ bond with hydrogen over platinum oxide, and deprotection gave principally (20*R*,23*R*,24*R*)-5α-dinosteran-29-ol. The further reduction of this alcohol provided (20*R*,23*R*,24*R*)-5α-dinosterane (**2b**). The application of the same sequence of reactions to (20*R*,23*S*)-5α-dinoster-24(28)-en-29-ol provided (20*R*,23*S*,24*S*)-5α-dinosterane (**2c**). Diastereoselectivity at the C-23 position in these ester alkylations was examined as a function of stereochemistry at both the C-20 and C-24 positions.

The formation of petroleum from biological materials under the conditions of high temperature and pressure over the course of geologic time results in the conversion of functionalized, terpenoid natural products to their corresponding hydrocarbon skeletons.[2] These "molecular fossils", or biological markers,[2] provide considerable information on the origin, maturation, migration, and microbiological degradation of crude oils. Among the many saturated steranes in crude oils in the C_{27} to C_{30} range, the C_{30} 4α-methyl-5α-steranes such as 4α-methyl-5α-stigmastane[3] (1) and 5α-dinosterane[4] (2) presumably derive from 4α-methylsterols in marine algae and represent characteristic biomarkers diagnostic of marine origins. Among the present day representatives of these skeletons are the C_{30} biosynthetic intermediates that are involved in the formation of plant sterols such as β-sitosterol (3). In addition, there are C_{30} sterols[5] such as dinosterol[6] (4) and related analogs that are isolated from unicellular algae in the phyllum, *Pyrrhophyta*. In order to confirm the stereochemistry of specific members of 4α-methyl-5α-stigmastane[3] (1) and 5α-dinosterane[4,7] (2) families detected by GC–MS techniques in crude oils,[2] we devised a synthesis of selected diastereomers of these C_{30} biomarkers.

As shown in Scheme I, a retroanalysis of the biomarker targets 1 and 2 suggested a 24-alkyl 4α-methyl-5α-cholestane-23-carboxylate (**5**) as a common precursor. Further disconnection of the ester **5** suggested either the alkylation of a lithocholate ester[8] **6** with an acyclic electrophile **7** (path a) or the alkylation of an acyclic ester **9** with a suitable electrophilic sterane **8** (path b) as logical disconnections of **5**. Of these two options, the latter path offered the best opportunity to control stereochemistry at the C-20, C-23, and C-24 positions, and the alkylation of

(1) For part 6 of this series, see: Stoilov, I.; Kolaczkowska, E.; St. Pyrek, J.; Brock, C. P.; Watt, D. S.; Carlson, R. M. K.; Moldowan, J. M. *Tetrahedron Lett.* **1992**, *33*, 7689.

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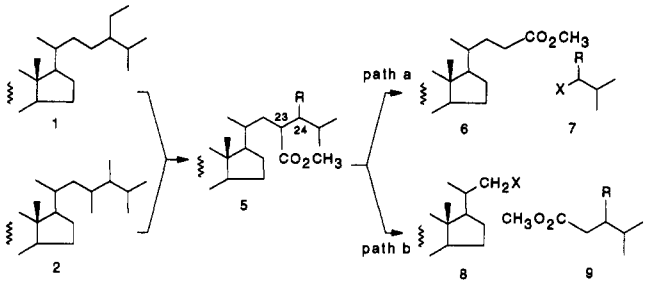
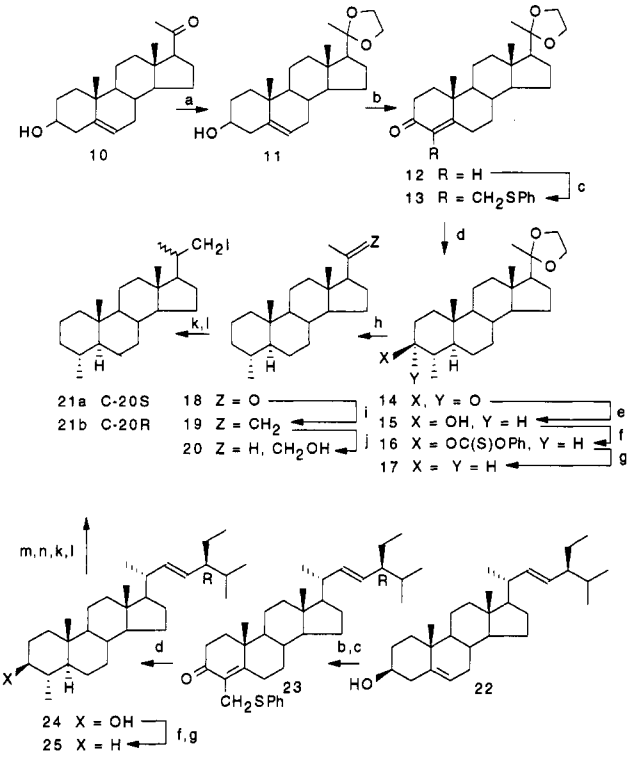
Scheme I. Retroanalysis



Scheme II. Synthesis of 20-(Iodomethyl)-4α-methyl-5α-pregnane (21)[a]



[a] Key: (a) $HOCH_2CH_2OH$, *p*-TsOH; (b) Al(O-i-Pr)$_3$, 1-methyl-4-piperidone; (c) PhSH, HCHO, Et_3N; (d) Li, NH_3; (e) $LiAlH_4$, THF; (f) PhOC(S)Cl, Py; (g) (n-Bu)$_3$SnH, AIBN, C_6H_6; (h) 1:2.5:5.5 HCl–HOAc–THF, (i) $Ph_3P{=}CH_2$, KO-t-Am, benzene; (j) BH_3-THF; NaOH, H_2O_2; (k) Et_3N, MsCl; (l) NaI, acetone; (m) O_3, Me_2S followed by NaOH, MeOH; (n) $NaBH_4$.

either saturated[9] or α,β-unsaturated acyclic esters[10] with sterane electrophiles successfully provided stereoselective routes to the biomarkers **1** and **2**.

According to the retroanalysis, the synthesis of (20*R*,24*R*)-4α-methyl-5α-stigmastane (**1**) required the electrophilic sterane, (20*S*)-20-(iodomethyl)-4α-methyl-5α-pregnane (**21a**), and methyl (3*R*)-3-ethyl-4-methylpentanoate.[11] As shown in Scheme II, the preparation of (20*S*)-20-(iodomethyl)-4α-methyl-5α-pregnane (**21a**) from pregnenolone (**10**) required the introduction of the 4α-methyl group and a one-carbon homologation of the C-20 ketone. The ketalization of pregnenolone[12] (**10**), Oppenauer oxidation[13] of the homoallylic alcohol **11**, and a Kirk–Petrow thiophenoxymethylation[14] of the enone **12** provided the α-(thiophenoxymethyl) enone **13**. The lithium in ammonia reduction of **13** effected both desulfurization and enone reduction to furnish the ketal ketone **14** having the 5α-stereochemistry and the 4α-methyl group.[15] Deoxygenation[16] at C-3 involved the further reduction of **14** to the alcohol **15**, conversion to the phenyl thiocarbonate **16**, and reduction of **16** with tri-*n*-butyltin hydride in order to secure the ketal **17**. The acid-catalyzed hydrolysis[17] of **17** to the ketone **18**, a Wittig reaction, and a hydroboration–oxidation of the olefin **19** delivered the alcohols **20** as a separable C-20 epimeric mixture. The individual conversion of these epimeric alcohols to the corresponding mesylates[18] and S_N2 substitution with sodium iodide[19] provided (20*S*)- and (20*R*)-20-(iodomethyl)-4α-methyl-5α-pregnane (**21a**) and (**21b**). As shown in Scheme II, the application of a similar sequence of reactions to (22*E*)-stigmasterol (**22**) provided an alternate source of **21a** and **21b**. Although both **21a** and **21b** were used in alkylation studies that will be described later in the paper, only the

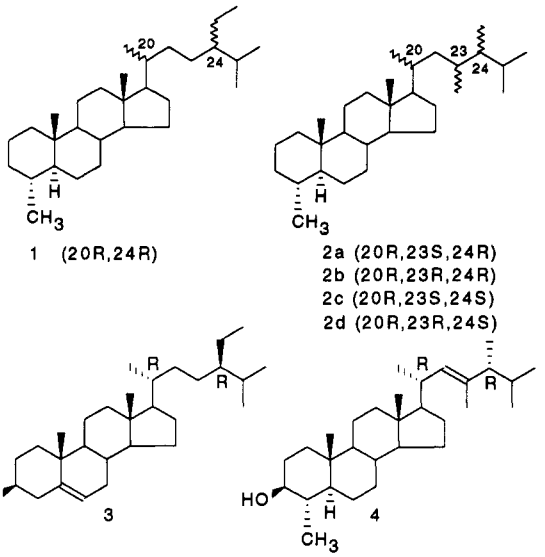


Figure 1.

(8) The alkylation of methyl (20*R*)-5β-cholanate or the alkylation of methyl (20*R*)-23-carbomethoxy-5β-cholananate with a suitable alkyl bromide did not provide an efficient pathway for side-chain construction. The enolate Claisen rearrangement of (2′*E*)-2′-methyl-2′-butenyl 5β-cholanate also failed to produce acceptable yields of the desired C-23 alkylated products. Finally, when efforts to introduce the C-4α methyl and invert the C-5β stereochemistry in cholanate systems proceeded in low overall yields, path a in Scheme I was abandoned.

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(17) Vigorous hydrolysis conditions (i.e., refluxing for 17 h in 1:2:3.5 1 M HCl–HOAc–THF) resulted in epimerization at C-17 to give a 4:1 ratio of **18** and 4α-methyl-5α,17β(H)-pregnan-20-one: mp 124–126.5 °C; IR ($CHCl_3$) 1690 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.78 (s, 3, C-18 CH_3), 0.79 (d, J = 6 Hz, 3, C-4α CH_3), 0.90 (s, 3, C-18 CH_3), 2.12 (s, 3, C-21 CH_3); ^{13}C NMR ($CDCl_3$) δ 12.9, 20.3, 20.7, 21.6, 24.0, 25.6, 31.0, 32.2, 32.6, 35.1, 35.3, 36.2, 38.6, 45.5, 50.3, 53.1, 53.8, 61.2, 213.2. Anal. Calcd for $C_{22}H_{36}O$: C, 83.48; H, 11.47. Found: C, 83.35; H, 11.46.

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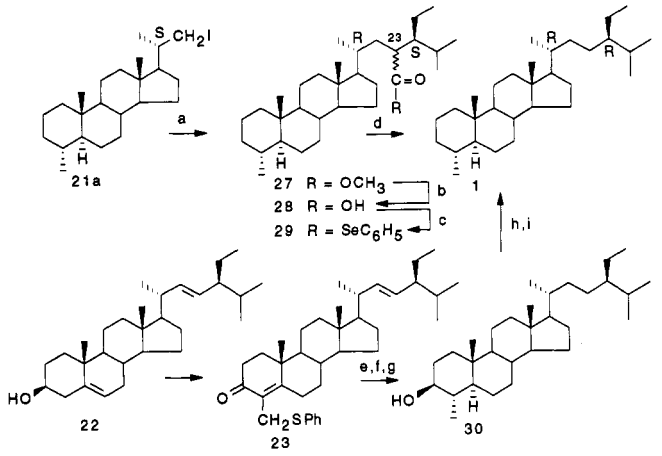
Scheme III. Synthesis of (20*R*,24*R*)-4α-Methyl-5α-stigmastane (1)[a]



[a] Key: (a) LDA, methyl (3*R*)-3-ethyl-4-methylpentanoate (**26**), THF, HMPA, −78 °C; (b) LiI, collidine, heat; (c) $PhOP(O)Cl_2$, Et_3N, PhSeH, Py; (d) $(n\text{-}Bu)_3SnH$; (e) Li, NH_3; (f) $LiAlH_4$, THF; (g) H_2, 10% Pd–C; (h) PhOC(S)Cl, Py, CH_2Cl_2; (i) $(n\text{-}Bu)_3SnH$, AIBN, C_6H_6.

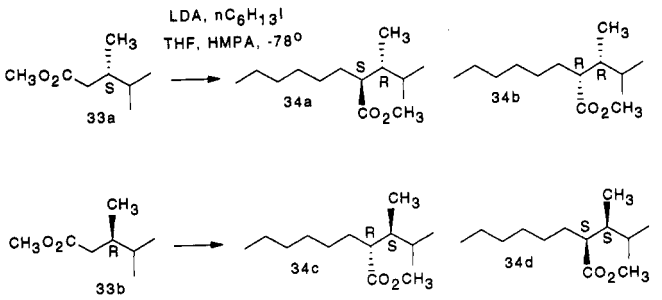


Figure 2.

(20*S*)-isomer **21a** was used in the synthesis of specific biomarkers.

As shown in Scheme III, the alkylation of methyl (3*R*)-3-ethyl-4-methylpentanoate[11] (**26**) with (20*S*)-20-(iodomethyl)-4α-methyl-5α-pregnane (**21a**) furnished methyl (20*R*,23ζ,24*S*)-4α-methyl-5α-stigmastane-23-carboxylate (**27a**) and (**27b**) as a mixture of C-23 epimers. Optimal conditions for the alkylation involved the use of a 7.5:5:5:1 ratio[20] of diisopropylamine, *n*-butyllithium, ester **26**, and iodide **21a** at temperatures of ca. −30 °C. It was interesting that this approach for constructing the C22,23 bond was more satisfactory than other alternatives including the condensation of a Grignard reagent derived from 1-bromo-2-ethyl-3-methylbutane with (20ζ)-4α-methyl-5α-pregnane-20-carboxaldehyde or the condensation of a Grignard reagent derived from (20ζ)-20-(iodomethyl)-4α-methyl-5α-pregnane (**21**) with 2-ethyl-3-methylbutanal.

Lithium iodide in refluxing collidine[21] effected saponification of the hindered carbomethoxy group in **27**. The conversion of the intermediate carboxylic acid **28** to the phenylseleno ester[22] **29** and reduction with tri-*n*-butyltin hydride provided (20*R*,24*R*)-4α-methyl-5α-stigmastane (**1**). An authentic sample of (20*R*,24*R*)-4α-methyl-5α-stigmastane (**1**) was also prepared from (22*E*)-stigmasterol (**22**) using the route summarized in Scheme III. The identity of **1** prepared from either **21a** or from **22** confirmed the C-20 stereochemical assignment of **21a** and set the stage for the preparation of selected C-20*R* diastereomers of 5α-dinosterane (**2**).

Previous efforts[23] to prepare 5α-dinosteranes (**2**) from dinosterol (**4**) were hampered by the limited supplies of **4**, the C-24 allylic epimerization during the hydrogenation of **4**, and the difficulties associated with the reversed-phase HPLC separation of the C-23,24 diastereomers of **2**. In order to prepare appreciable quantities of selected 5α-dinosteranes (**2**) by the route suggested in Scheme I, we needed to define the factors that controlled C-23 diastereoselection in the alkylation of chiral esters with chiral sterane electrophiles. To this end, we completed a series of studies involving the alkylation of chiral esters with achiral electrophiles, the alkylation of achiral esters with (20*S*)- and (20*R*)-20-(iodomethyl)-4α-methyl-5α-pregnane (**21a**) and (**21b**), and finally the alkylation of chiral esters with **21a** and **21b**.

We began by investigating the diastereoselectivity of alkylations of chiral esters with achiral electrophiles. An enantioselective reduction of methyl (2*E*)- or (2*Z*)-3,4-dimethyl-2-pentenoate (**32a**) or (**32b**) with sodium borohydride in conjunction with a cobalt–semicorrin complex[24] provided methyl (3*S*)- or (3*R*)-3,4-dimethylpentanoate (**33a**) and (**33b**), respectively. As shown in Figure 2, the alkylation of ester **33a** with an achiral iodide, *n*-hexyl iodide, led to a 4:1 mixture of the erythro- and threo-diastereomers **34a** and **34b**, respectively. In a similar fashion, the alkylation of ester **33b** led to a 4:1 mixture of the erythro- and threo-diastereomers **34c** and **34d**. The optimal conditions for this alkylation again involved the use of a 7.5:5:5:1 ratio of diisopropylamine, *n*-butyllithium, ester **33a** or **33b**, and *n*-hexyl iodide at temperatures of ca. −30 °C. An alkylation performed with an equimolar ratio of these reagents led to a similar ratio of products and excluded the possibility that the excess of the ester enolate present in the former alkylation promoted equilibration of the erythro- and threo-products.

The erythro-selectivity was consistent with a model involving S_N2 attack by the *Z*-enolate of either **33a** or **33b** on *n*-hexyl iodide. As shown in Figure 3, this model assumed that an unfavorable, intramolecular steric interaction between the C-3 methyl group and the lithium alkoxide of the enolate disfavored conformers C and D in which the incoming electrophile approached from the side opposite the bulky isopropyl group. The absence of this unfavorable steric interaction in conformers A and B favored the erythro products **34a** and **34c**. This model differed from the Felkin–Anh model in which the principal steric interaction involved the incoming nucleophile and the proximal substituent on the adjoining chiral center. That is, a strict application of the Felkin–Anh model to the conformers in Figure 3 would predict that conformers C and D would be favored over conformers A and B since

(20) 20-(Iodomethyl)-4α-methyl-5α-pregnane is sparingly soluble at −78 °C in 6% HMPA–THF mixtures. An alkylation performed and quenched at −78 °C led principally to unreacted iodide and products derived from a Claisen condensation of the ester.

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(23) PCC oxidation of a sample of dinosterol (**4**), contaminated with (24*R*)-4α,24-dimethyl-5α-cholestan-3β-ol, followed by a Wolff–Kishner reduction furnished (22*E*)-5α-dinoster-22-ene. Catalytic hydrogenation using palladium on carbon proceeded with epimerization[6e] at C-24 and provided (20*R*,23ζ,24ζ)-5α-dinosterane (**2**) as a mixture of four diastereomers that were separated by reversed-phase HPLC. No epimerization at the other allylic C-20 position was observed during these catalytic hydrogenations.[6e]

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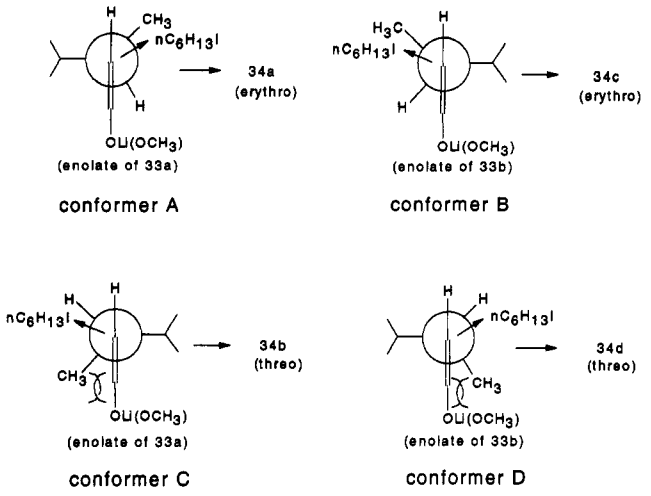


Figure 3.

the former minimized steric interactions between the *n*-hexyl iodide and the proximal C-3 methyl group. The model proposed here discounted this steric interaction as less important than the interaction of the lithium alkoxide and the C-3 methyl group.

The influence of the chirality of the C-20 stereocenter in the sterane electrophiles **21a** and **21b** on C-23 diastereoselectivity was examined in alkylations with achiral, saturated and unsaturated esters: methyl pentanoate (**35**), methyl 4-methylpentanoate (**36**), and methyl (2*Z*)-3,4-methyl-2-pentenoate[25] (**32**). The alkylation of **21a** with the saturated ester, methyl pentanoate (**35**) (entry 1, Table I), exhibited a 5.1:1 preference for the "α-oriented" epimer **37a** relative to the "β-oriented" epimer **37b**. The alkylation of methyl pentanoate (**35**) with the enantiomeric electrophile **21b** (entry 2, Table I) exhibited a similar 5.3:1 preference for the "α-oriented" epimer **37c** relative to the "β-oriented" epimer **37d**. In the same fashion, the alkylation of **21a** with methyl 4-methylpentanoate (**36**) (entry 3, Table I), exhibited a 6.6:1 preference for the "α-oriented" epimer **38a** relative to the "β-oriented" epimer **38b**. Finally, the alkylation of **21a** or **21b** with the *α,β-unsaturated* ester, methyl 3,4-dimethyl-2-pentenoate (**32**) (entries 4 and 5, Table I), also displayed an approximate 2:1 preference for the "α-oriented" epimers **39a** or **39c** relative to the "β-oriented" epimers **39b** or **39d**, respectively. In summary, the chirality of the sterane electrophile favored "α-selectivity" at C-23 to a slight degree, but changing a single chiral center at C-20 in the electrophile, despite its proximity to the electrophilic terminus, had little influence. This finding was consistent with other alkylations[26] in which distal, acyclic, chiral centers had limited impact on diastereoselectivity.

Finally, it was of interest to examine the outcome of alkylations in which the "erythro-selectivity" that was noted in the alkylation of *achiral* electrophiles with *chiral* esters (Figure 2) was juxtaposed with the "α-selectivity" noted in the alkylation of *chiral* electrophiles **21a** and **21b** with *achiral* esters (entries 1–5, Table I). As shown in Table I, the alkylation of methyl (3*R*)-3,4-methylpentanoate (**33b**) (entries 6 and 7, Table I) with **21a** or **21b** led principally to the "α-erythro" diastereomers **40a** and **40c**, respectively, favored both by "erythro-selectivity" and "α-selectivity" expectations. In the same fashion, the alkylation of methyl (3*R*)-3-ethyl-4-methylpentanoate (**26**) (entries 10 and 11, Table I) with **21a** or **21b** again led principally to the "α-erythro" diastereomers **27a** and **27c**, respectively, in which both "erythro-selectivity" and "α-selectivity" favored the same outcome. It was interesting that the level of diastereoselection at C-23 in these cases was not appreciably different from that observed in the absence of a C-24 stereocenter (*i.e.*, comparison of entries 6, 7, 10, and 11 with entries 1, 2, and 3, Table I). However, as shown in Table I, the alkylation of methyl (3*S*)-3,4-methylpentanoate (**33a**) (entries 8 and 9, Table I) with **21a** or **21b** favored the "β-erythro" diastereomers **40f** or **40h** over the "α-threo" diastereomers **40e** and **40g**. The dominance of "erythro-selectivity" over "α-selectivity" in entries 8 and 9 in Table I presumably resulted from the more pronounced influence of the proximal C-24 stereocenter than of the distal sterane stereocenters.

The syntheses of the C-23 and C-24 erythro-diastereomers of (20*R*)-5α-dinosterane (**2a**) and (**2d**) were completed as shown in Scheme IV. The alkylation of methyl (3*S*)-3,4-dimethylpentanoate (**33a**) with **21a** led to a 4:1 ratio of the inseparable erythro- and threo-diastereomers **40f** and **40e**. The reduction of this mixture provided the corresponding alcohols **41f** and **41e** that were readily separated by silica gel chromatography. An X-ray crystallographic study of the principal isomer, (20*R*,23*S*,24*R*)-5α-dinosteran-29-ol (**41f**), confirmed the C-23*S* stereochemical assignment.[27] The further reduction of the mesylate of (20*R*,23*S*,24*R*)-**41f** provided (20*R*,23*S*,24*R*)-5α-dinosterane (**2a**). As shown in Scheme IV, the repetition of the alkylation of **21a** using methyl (3*R*)-3,4-dimethylpentanoate (**33b**), reduction of the C-23 epimeric esters **40a** and **40b**, separation of the principal alcohol **41a**, and the further reduction of this alcohol led to (20*R*,-23*R*,24*S*)-5α-dinosterane (**2d**).

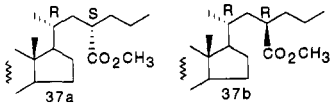
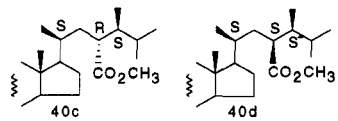
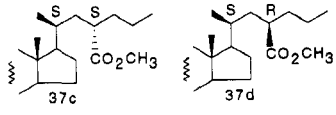
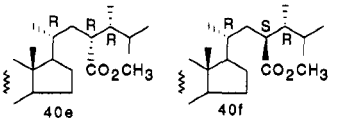
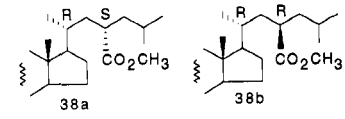
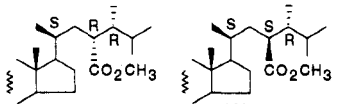
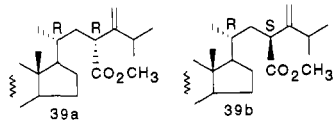
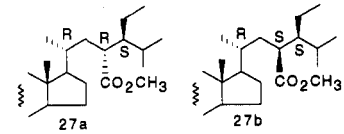
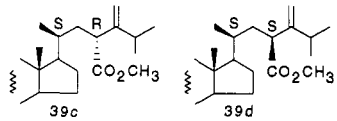
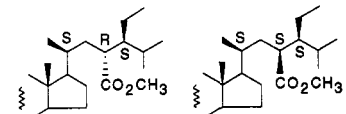
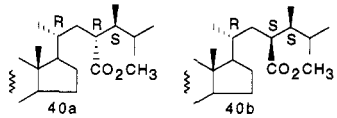
The alkylation of the *saturated* esters **33a** and **33b** with **21a** in Scheme IV produced only minor amounts of the threo-esters **40e** and **40b** and was not a practical source of appreciable quantities of the threo-diastereomers of (20*R*)-5α-dinosterane (**2b**) and (**2c**). As shown in Scheme V, the alkylation of the *α,β-unsaturated* ester, methyl 3,4-dimethyl-2-pentenoate (**32**), provided a selective route to these diastereomers. The alkylation of **32** with **21a** provided a 2.4:1 ratio of the β,γ-unsaturated esters **39a** and **39b**. The reduction of the esters afforded the separable homoallylic alcohols **42a** and **42b**, respectively. Although the direct reduction of either of these homoallylic alcohols **42a** and **42b** to the corresponding saturated alcohols exhibited little diastereoselectivity at C-24, the conversion of the individual homoallylic alcohol **42a** to the corresponding *tert*-butyldimethylsilyl ether, catalytic hydrogenation over platinum, and deprotection provided principally the saturated alcohol **41e** and a lesser amount of **41a**. In the same fashion, the homoallylic alcohol **42b** provided principally **41b** and a lesser amount of **41f**. The final reduction of the mesylates of these threo-isomers **41e** and **41b** furnished the remaining biomarkers, (20*R*,-23*R*,24*R*)-5α-dinosterane (**2b**) and (20*R*,23*S*,24*S*)-5α-dinosterane[28] (**2c**), respectively.

(25) For a similar procedure leading to the ethyl esters, see: Huffman, J. W.; Starnes, J. J. *J. Org. Chem.* **1972**, *37*, 487.

(26) Evans, D. A. *Asymmetric Synthesis: Stereodifferentiating Addition Reactions Part B*; Morrison, J. D., Ed.; Academic: New York, 1984; Chapter 1, p 85.

(27) The details of the X-ray crystallographic study will be reported in *Acta Crystallogr., Sect. C.*

Table I. Diastereoselection in the Alkylation of Methyl (3*R*)-3-Ethyl-4-methylpentanoate (26), Methyl (2*S*)-3,4-Methyl-2-pentenoate (32), Methyl (3*S*)- or (3*R*)-3,4-Dimethylpentanoate (33a) and (33b), Methyl Pentanoate (35), and Methyl 4-Methylpentanoate (36)

entry	ester	electrophile	products and epimer ratios[a]	entry	ester	electrophile	products and epimer ratios[a]
1	 35	21a	 37a 37b 5.1 : 1	7	 33b	21b	 40c 40d 4 : 1
2	 35	21b	 37c 37d 5.3 : 1	8	 33a	21a	 40e 40f 1 : 4
3	 36	21a	 38a 38b 6.6 : 1	9	 33a	21b	 40g 40h 1 : 4
4	 32	21a	 39a 39b 2.4 : 1	10	 26	21a	 27a 27b 3 : 1
5	 32	21b	 39c 39d 2.2 : 1	11	 26	21b	 27c 27d 3 : 1
6	 33b	21a	 40a 40b 4 : 1				

[a] Product ratios were determined by GC analysis on an SE-30 fused silica gel capillary column (15 m) at 250–290 °C using He as a carrier gas.

In summary, the alkylations of various acyclic esters with chiral and achiral iodides (Table I and Figure 2) highlighted some of the factors that influence diastereoselection. The alkylation of the *saturated* esters, methyl (3*S*)- and (3*R*)-3,4-dimethylpentanoate (**33a**) and (**33b**), with (20*S*)-20-(iodomethyl)-4α-methyl-5α-pregnane (**21a**) provided predominantly the erythro-diastereomers, and the further reduction of these diastereomers provides (20*R*,23*S*,24*R*)- and (20*R*,23*R*,24*S*)-5α-dinosteranes (**2a**) and (**2d**). A similar alkylation of methyl (3*R*)-3-ethyl-4-methylpentanoate[11] (**26**) with **21a** followed by decarbomethoxylation provided an avenue to (20*R*,24*R*)-4α-methyl-5α-stigmastane (**1**). The alkylation of the α,β-*unsaturated* ester methyl 3,4-dimethyl-2-pentenoate (**32**) with **21a** and the further reduction of the products provided access to the threo-diastereomers (20*R*,23*R*,24*R*)- and (20*R*,23*S*,24*S*)-5α-dinosterane (**2b**) and (**2c**). These approaches for the selective synthesis of individual diastereomers of sterane biomarkers will prove valuable in continuing studies to synthesize other biomarkers in the C_{30} mono- and triaromatic dinosterane families.[29]

(28) It should be noted that the separation of **41b** and **41f** in Scheme V required a tedious HPLC separation. Consequently, the preparation of a pure sample of **2c** was most easily accomplished using the minor isomer **41b** that had been separated from the mixture of **41a** and **41b** produced by the route shown in Scheme IV.

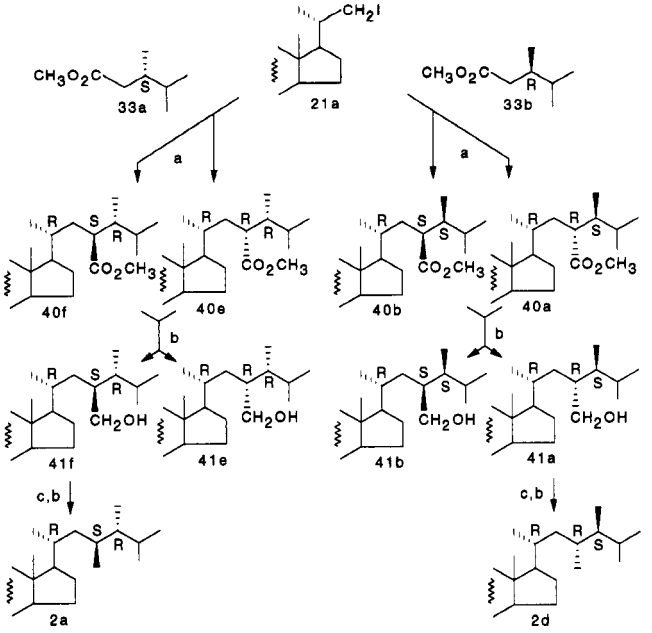
Experimental Section

Pregnenolone Ethylene Ketal (11). The procedure of Bach[12b] was repeated using 10 g (32 mmol) of pregnenolone (**10**) and 400 mg of *p*-toluenesulfonic acid monohydrate in 350 mL of distilled ethylene glycol to afford, after the ethylene glycol was distilled from the mixture at 80–85 °C (1 mm) over a 9-h period, 9 g (79%) of **11**: mp 158–61 °C (lit.[12b] mp 160–163 °C); ^{1}H NMR ($CDCl_3$) δ 0.70 (s, 3, C-18 CH_3), 1.01 (s, 3, C-19 CH_3), 1.30 (s, 3, C-21 CH_3), 3.40–3.60 (m, 1, C*H*(OH)), 3.80–4.08 (m, 4, OCH_2CH_2O), 5.34–5.40 (m, 1, C-6 vinylic H); ^{13}C NMR ($CDCl_3$) δ 12.6, 19.2, 20.6, 22.7, 23.6, 24.4, 31.2, 31.4, 31.6, 36.3, 37.1, 39.2, 41.6, 42.1, 49.9, 56.5, 58.1, 63.1, 65.1, 71.7, 112.1, 121.7, 141.0.

Progesterone 20-Ethylene Ketal (12). The procedure of Raggio[13] was repeated using 18.5 g (51.4 mmol) of **11** in 300 mL of toluene, 48 mL (44.1 g, 7.6 equiv) of distilled 1-methyl-4-piperidone, and 30.5 g (0.15 mol, 2.91 equiv) of Al(O-*i*-Pr)$_3$ under a Dean-Stark trap to afford, after chromatography on a silica gel column using 1:1 EtOAc–hexane, 14.3 g (78%) of **12**, mp 189.5–190.5 °C. A sample was recrystallized from MeOH: mp 190–192 °C (lit.[11a] mp 189–90 °C; lit.[11b] mp 187–192.5 °C); ^{1}H NMR ($CDCl_3$) δ 0.81 (s, 3, C-18 CH_3), 1.19 (s, 3, C-19 CH_3), 1.30 (s, 3, C-21 CH_3),

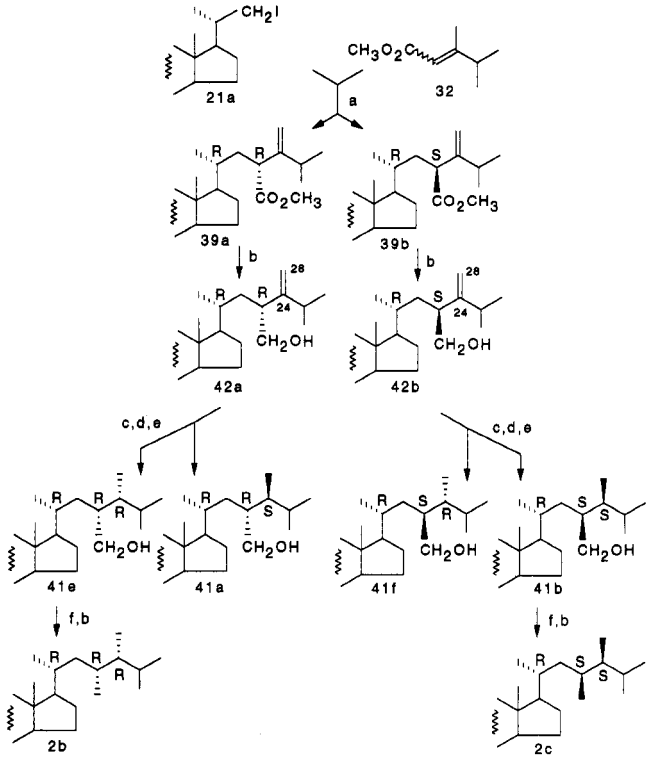
(29) (a) Lichtfouse, E.; Riolo, J.; Albrecht, P. *Tetrahedron Lett.* **1990**, *31*, 3937. (b) Carlson, R. M. K.; Chamberlain, D. E. *Org. Geochem.* **1986**, *10*, 163. (c) Shi, J. Y.; Mackenzie, A. S.; Alexander, R.; Eglinton, G.; Gowar, A. P.; Wolff, G. A.; Maxwell, J. R. *Chem. Geol.* **1982**, *35*, 1. (d) Ludwig, B.; Hussler, G.; Wehrung, P.; Albrecht, P. *Tetrahedron Lett.* **1981**, *22*, 3313. (e) Mackenzie, A. S.; Hoffmann, C. F.; Maxwell, J. R. *Geochim. Cosmochim. Acta* **1981**, *45*, 1345.

Scheme IV. Synthesis of Erythro-Diastereomers of 5α-Dinosterane (2)[a]



[a] Key: (a) LDA, HMPA, THF, −78 °C; (b) $LiAlH_4$ followed by chromatographic separation; (c) MsCl, Et_3N.

Scheme V. Synthesis of Threo-Diastereomers of 5α-Dinosterane (2)[a]



[a] Key: (a) LDA, HMPA, THF, −78 °C; (b) $LiAlH_4$; (c) TBSCl, imidazole; (d) H_2, PtO_2; (e) $(n\text{-}Bu)_4NF$; (f) MsCl, Et_3N.

3.80–4.10 (m, 4, OCH_2CH_2O), 5.72–5.78 (m, 1, C-6 vinylic H); ^{13}C NMR ($CDCl_3$) δ 12.6, 17.1, 20.5, 22.6, 23.5, 24.3, 31.7, 32.7, 33.8, 34.9, 35.5, 38.4, 39.1, 41.6, 53.6, 55.6, 58.0, 63.1, 65.1, 111.9, 123.9, 171.9, 200.1.

4-((Phenylthio)methyl)-4-pregnene-3,20-dione 20-Ethylene Ketal (13). The procedure of Kirk[14] was repeated with modifications. A mixture of 14.6 g (40.7 mmol) of **12**, 11.7 g (10.9 mL, 2.6 equiv) of thiophenol, 8.75 g (21.8 mL, 7.16 equiv) of a 37% aqueous solution of formaldehyde, and 8.73 g (12 mL, 2.12 equiv) of Et_3N in 90 mL of EtOH was refluxed for 72 h. The EtOH was evaporated; the yellow viscous oil was dissolved in Et_2O; and the organic solution was washed successively with aqueous NaOH solution and brine and dried over anhydrous $MgSO_4$. The solvents were evaporated to afford a yellow viscous oil which was chromatographed on a silica gel column using 1:5 EtOAc-hexane to give 10.6 g (54%) of **13**: mp 124–124.5 °C; IR ($CHCl_3$) 1660 (C=O), 1595 (C=C) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.79 (s, 3, C-18 CH_3), 1.15 (s, 3, C-19 CH_3), 1.29 (s, 3, C-21 CH_3), 3.82–4.04 (m, 6, OCH_2CH_2O and CH_2SPh), 7.17–7.43 (m, 5, ArH); ^{13}C NMR ($CDCl_3$) δ 12.6, 17.6, 20.5, 22.7, 23.4, 24.3, 27.9, 28.6, 31.6, 33.4, 34.4, 34.6, 39.1, 39.2, 41.6, 54.0, 55.6, 58.0, 63.1, 65.1, 111.8, 126.6, 128.3, 128.8, 131.1, 136.6, 168.5, 197.4 (C=O); exact mass spectrum calcd for $C_{30}H_{40}SO_3$ 480.2700, found 480.2699. Anal. Calcd for $C_{30}H_{40}SO_3$: C, 74.95; H, 8.39. Found: C, 74.84; H, 8.42.

4α-Methyl-5α-pregnane-3,20-dione 20-Ethylene Ketal (14). To 1.63 g (235 mmol, 3.7 equiv) of lithium in 250 mL of liquid NH_3 (distilled from sodium) at −78 °C under N_2 was added 5.07 g (10.5 mmol) of **13** in 50 mL of anhydrous THF. The dark blue solution was stirred at −78 °C for 5 h, and the reaction was quenched with 15 g of NH_4Cl. To this solution was added 100 mL of Et_2O, and the NH_3 was allowed to evaporate. The residue was dissolved in water and extracted with Et_2O. The organic layer was washed with brine, dried over anhydrous $MgSO_4$, concentrated, and chromatographed on silica gel using 1:5 EtOAc-hexane to furnish 2.15 g (54%) of **14**: mp 200–202 °C; IR ($CHCl_3$) 1695 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.78 (s, 3, C-18 CH_3), 0.97 (d, J = 6.6 Hz, 3, C-4α CH_3), 1.07 (s, 3, C-19 CH_3), 1.29 (s, 3, C-21 CH_3), 3.82–4.10 (m, 4, OCH_2CH_2O); ^{13}C NMR ($CDCl_3$) δ 11.2, 12.5, 12.8, 20.9, 22.7, 23.5, 24.4, 25.4, 31.6, 34.2, 36.2, 37.9, 39.1, 39.4, 41.8, 44.9, 53.5, 53.9, 56.1, 58.2, 63.1, 65.1, 112.0, 214.3 (C=O). Anal. Calcd for $C_{24}H_{38}O_3$: C, 76.96; H, 10.23. Found: C, 76.72; H, 10.25.

4α-Methyl-3β-hydroxy-5α-pregnan-20-one Ethylene Ketal (15). To 125 mg (3.29 mmol, 2 equiv) of $LiAlH_4$ in 50 mL of anhydrous THF was added 2.47 g (6.59 mmol) of **14** in 115 mL of anhydrous THF dropwise over a period of 30 min. The mixture was stirred at 25 °C for 2.5 h. To the mixture at 0 °C was added slowly 125 mL of water followed by 375 mL of 15% aqueous NaOH and finally by 375 mL of water. The product was diluted with Et_2O, filtered, and washed with brine. The Et_2O solution was dried over anhydrous $MgSO_4$ and concentrated to afford 2.15 g (87%) of **15** that was principally the C-3β epimer. An analytical sample was prepared by recrystallization from MeOH: mp 193–195.5 °C; IR ($CHCl_3$) 3610 (OH) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.75 (s, 3, C-18 CH_3), 0.83 (s, 3, C-19 CH_3), 0.95 (d, J = 6.2 Hz, 3, C-4α CH_3), 1.29 (s, 3, C-21 CH_3), 3.00–3.20 (m, 1, C*H*OH), 3.80–4.05 (m, 4, CH_2CH_2O); ^{13}C NMR ($CDCl_3$) δ 12.8, 13.1, 14.9, 20.7, 22.7, 23.5, 23.9, 24.4, 30.9, 31.9, 34.1, 35.8, 39.0, 39.5, 41.8, 50.8, 54.4, 56.3, 58.2, 63.1, 65.2, 76.5, 112.1. Anal. Calcd for $C_{24}H_{40}O_3$: C, 76.54; H, 10.70. Found: C, 76.38; H, 10.65.

4α-Methyl-3β-hydroxy-5α-pregnan-20-one Ethylene Ketal Phenyl Thiocarbonate (16). The procedure of Robins[16c] was repeated using 408 mg (1.08 mmol) of **15**, 281 mg (225 mL, 1.62 mmol) of phenyl thionochloroformate, 343 mg (347 μL, 4.33 mmol) of anhydrous pyridine, and 24 mL of anhydrous CH_2Cl_2 to afford, after chromatography on silica gel using 1:10 EtOAc–hexane, 401 mg (78%) of **16**: mp 195–196.5 °C; IR ($CHCl_3$) 1550, 1470, 1430, 1365, 1355, 1315, 1275, 1175, 1130, 1055, 1035 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.76 (s, 3, C-18 CH_3), 0.88 (s, 3, C-19 CH_3), 0.94 (d, J = 6.2 Hz, 3, C-4α CH_3), 1.29 (s, 3, C-21 CH_3), 3.80–4.05 (m, 4, OCH_2CH_2O), 4.82–5.0 (m, 1, C*H*OC(S)OPh), 7.0–7.5 (m, 5, Ar); ^{13}C NMR ($CDCl_3$) δ 12.8, 13.0, 14.9, 20.7, 22.7, 23.4, 23.8, 24.3, 25.6, 31.8, 34.1, 35.7, 36.0, 36.1, 39.4, 41.7, 50.8, 54.1, 56.2, 58.2, 63.1, 65.1, 90.1, 112.0, 122.2, 126.5, 129.6, 153.5, 195.3. Anal. Calcd for $C_{31}H_{44}SO_3$: C, 72.61; H, 8.65. Found: C, 72.55; H, 8.68.

4α-Methyl-5α-pregnan-20-one Ethylene Ketal (17). A solution of 3.05 g (2.83 mL, 10.5 mmol) of $(n\text{-}Bu)_3SnH$ in 30 mL of anhydrous benzene was added dropwise over a 3.5-h period to a refluxing solution of 1.63 g (3.18 mmol) of **16** and 0.052 g (0.32 mmol) of 2,2′-azobisisobutyronitrile in 200 mL of anhydrous benzene. The mixture was refluxed an additional 4 h, cooled, and diluted with Et_2O. The solution was washed successively with cold 1 M HCl solution, water, 5% NaOH, and brine, and dried over anhydrous $MgSO_4$. The crude product was chro-

matographed on silica gel using 1:10 EtOAc–hexane to afford 945 mg (82%) of **17**: mp 134–135 °C; IR ($CHCl_3$) 3000–2820, 1430, 1370, 1230–1190, 1040 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.74 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6 Hz, 3, C-4α CH_3), 1.29 (s, 3, C-21 CH_3), 3.82–4.10 (m, 4, OCH_2CH_2O); ^{13}C NMR ($CDCl_3$) δ 12.8, 13.0, 20.4, 20.6, 21.7, 22.7, 23.5, 24.1, 24.4, 31.1, 32.0, 34.2, 36.3, 36.4, 38.7, 39.6, 41.7, 53.4, 54.7, 56.5, 58.3, 63.1, 65.2, 112.1 (C-20). Anal. Calcd for $C_{24}H_{40}O_2$: C, 79.94; H, 11.18. Found: C, 79.98; H, 11.14.

4α-Methyl-5α-pregnan-20-one (18). A solution of 1.01 g (2.8 mmol) of **17** in 120 mL of 1:2.5:5.5 mixture of 1 M HCl–HOAc–THF was stirred at 25 °C for 2 h. The mixture was poured into 200 mL of cold water. The organic was separated, and the aqueous layer was extracted with EtOAc. The combined organic layers were washed successively with saturated $NaHCO_3$ solution and brine and dried over anhydrous $MgSO_4$. The product was chromatographed on silica gel using 1:10 EtOAc–hexane to afford 760 mg (86%) of **18**: mp 159–160 °C; IR ($CHCl_3$) 1705 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.59 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.80 (d, J = 6.4 Hz, 3, C-4α CH_3), 2.11 (s, 3, C-21 CH_3); ^{13}C NMR ($CDCl_3$) δ 13.0, 13.2, 20.3, 20.8, 21.6, 22.5, 23.9, 24.1, 31.0, 31.3, 32.0, 34.9, 36.3, 38.7, 39.0, 44.0, 53.3, 54.5, 56.8, 63.8, 210.2 (21 lines; one line represents two carbons); ^{13}C NMR ($CDCl_3$) (with 5% of $Eu(fod)_3$) δ 13.3, 13.9, 20.6, 21.1, 21.9, 23.3, 24.2, 24.6, 31.3, 32.3, 32.7, 35.2, 36.49, 36.54, 38.9, 39.5, 44.7, 53.5, 54.8, 57.2, 64.5, 211.9; exact mass spectrum calcd for $C_{22}H_{36}O$ 316.2767, found 316.2766. Anal. Calcd for $C_{22}H_{36}O$: C, 83.48; H, 11.47. Found: C, 83.40; H, 11.44.

4α-Methyl-20-methylene-5α-pregnane (19). To a suspension of 2.56 g (7.17 mmol) of methyltriphenylphosphonium bromide in 8 mL of anhydrous benzene under N_2 was added 905 mg of 1.66 M (7.17 mmol) potassium *tert*-amylate in benzene. The mixture was refluxed for 1 h, and 337 mg (1.06 mmol) of **18** in 7.5 mL of anhydrous benzene was added. The mixture was refluxed for 4.5 h and stirred for 12 h at 25 °C. The mixture was poured into water and extracted with Et_2O. The combined organic layers were washed successively with 10% HCl solution, saturated $NaHCO_3$ solution, and brine, and dried over anhydrous $MgSO_4$. The crude product was chromatographed twice on silica gel with hexane to afford 306 mg (91%) of **19**: mp 156.5–159 °C: IR ($CHCl_3$) 1630 (C=C), 1440, 1370 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.55 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.80 (d, J = 6.4 Hz, 3, C-4α CH_3), 1.75 (s, 3, C-21 CH_3), 4.70 (s, 1, vinylic H), 4.84 (s, 1, vinylic H); ^{13}C NMR ($CDCl_3$) δ 12.6, 13.0, 20.4, 20.8, 21.7, 23.9, 24.1, 24.5, 25.2, 31.1, 32.0, 35.3, 36.4, 38.7, 38.9, 43.1, 53.4, 54.8, 56.4, 57.3, 110.6 (C-22), 146.1 (C-20). Anal. Calcd for $C_{28}H_{38}$: C, 87.82; H, 12.18. Found: C, 87.79; H, 12.15.

(20*S*)- and (20*R*)-20-(Hydroxymethyl)-4α-methyl-5α-pregnane (20a) and (20b) from 19. To a suspension of 362 mg (1.15 mmol) of **19** in 1.15 mL of anhydrous THF at 0 °C under N_2 was added 864 mL (0.864 mmol) of 1 M borane–THF solution via a syringe over a 10-min period. The ice bath was removed, and the clear solution was stirred at 25 °C for 1 h. The mixture was again cooled to 0 °C, and the excess borane was destroyed with 100 mL of water. To this solution was added 960 mL (2.88 mmol) of 3 M NaOH solution followed by 960 mL (2.88 mmol) of a 30% H_2O_2 solution. The mixture was initially viscous and was heated for 3.5 h at 53–54 °C. The solution was cooled, and the phases were separated. The aqueous layer was extracted with Et_2O. The combined organic layers were washed with brine and dried over anhydrous $MgSO_4$. The product was chromatographed on silica gel using 1:5 EtOAc–hexane to afford 312 mg (81%) of **20** as a C-20 epimeric mixture: mp 157–159 °C; IR ($CHCl_3$) 3610 (OH), 1445, 1435, 1370 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.67 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.80 (d, J = 6.4 Hz, 3, C-4α CH_3), 0.95 and 1.03 (two d, J = 6.6 Hz, 3, C-21S and C-21R CH_3), 3.30–3.80 (m, 2, CH_2OH). Anal. Calcd for $C_{23}H_{40}O$: C, 83.06; H, 12.12. Found: C, 82.94; H, 12.09. The mixture was separated on silica gel using 1:10 EtOAc–hexane to afford the individual epimers having the following physical and spectral data. Data for the C-20*S* epimer **20a**: mp 156.5–157 °C; IR ($CHCl_3$) 3610 (OH), 1445, 1435, 1370 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.67 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.4 Hz, 3, C-4α CH_3), 0.95 (d, J = 6.6 Hz, 3, C-21 CH_3), 3.40–3.80 (m, 2, CH_2OH); ^{13}C NMR ($CDCl_3$) δ 12.2, 13.0, 16.5, 20.4, 20.7, 21.7, 23.8, 24.0, 27.5, 31.1, 32.0, 34.8, 36.2, 36.3, 37.8, 38.7, 39.5, 42.1, 54.2, 53.3, 54.6, 56.5, 66.8 (CH_2OH). Data for the C-20*R* epimer **20b**: mp 167–168 °C; IR ($CHCl_3$) 3610 (OH), 1435, 1370 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.67 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.80 (d, J = 6.4 Hz, 3, C-4α CH_3), 1.03 (d, J = 6.6 Hz, 3, C-21 CH_3), 3.30–3.70 (m, 2, CH_2OH); ^{13}C NMR ($CDCl_3$) δ 11.9, 13.0, 16.4, 20.4, 20.7, 21.7, 24.0, 27.6, 31.1, 32.0, 34.9, 36.2, 36.3, 38.7, 39.8, 42.4, 52.4, 53.3, 54.6, 56.3, 68.0 (CH_2OH).

(20*S*)- and (20*R*)-20-(Hydroxymethyl)-4α-methyl-5α-pregnane (20a) and (20b) from 25. The procedure of Shu[6c] was repeated using 410 mg (1 mmol) of **25** in 20 mL of CH_2Cl_2 and a slight excess of O_3. The mixture was quenched with 369 μL (5 mmol, 5 equiv) of dimethyl sulfide and warmed to 25 °C. The solution was concentrated and dissolved in 10 mL of MeOH containing 40 mg (1 mmol, 1 equiv) of NaOH. The solution was refluxed for 5 min and cooled. To this solution was added 76 mg (2 mmol, 8 equiv) of $NaBH_4$ to afford 241 mg (73%) of **20a** and **20b** as a 1:1 mixture. In the absence of the methanolic NaOH equilibration step, **25** was converted exclusively to **20a**.

(20*S*)-20-(Iodomethyl)-4α-methyl-5α-pregnane (21a). The procedure of Crossland[18] was repeated using 1.33 g (4 mmol) of **20a** and 504 mg (4.4 mmol, 1.1 equiv) of CH_3SO_2Cl to give 1.57 g (96%) of (20S)-20-hydroxymethyl-4α-methyl-5α-pregnane mesylate. The procedure of Partridge[19] was repeated using 1.57 g (3.8 mmol) of (20S)-20-(hydroxymethyl)-4α-methyl-5α-pregnane mesylate and 5.76 (38 mmol, 10 equiv) of NaI to give 1.44 g (85%) of **21a**: mp 152–153 °C; IR ($CHCl_3$) 2910, 1440, 1370 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.68 (s, 3, C-18 CH_3), 0.79 (d, J = 6.2 Hz, 3, C-4α CH_3), 0.79 (s, 3, C-19 CH_3), 1.01 (d, J = 5.2 Hz, 3, C-21 CH_3), 3.12–3.36 (m, 2, CH_2I); ^{13}C NMR ($CDCl_3$) δ 12.8, 13.2, 20.6, 20.7, 20.9, 21.3, 21.9, 24.0, 24.2, 27.6, 31.2, 32.2, 35.1, 36.4, 36.5, 37.0, 38.8, 39.8, 42.5, 53.4, 54.6, 55.5, 56.3. Anal. Calcd for $C_{23}H_{39}I$: C, 62.43; H, 8.88. Found: C, 62.41; H, 8.91.

(20*R*)-20-(Iodomethyl)-4α-methyl-5α-pregnane (21b). The procedure of Crossland[18] was repeated using 253 mg (0.76 mmol) of **20b** and 96 mg (0.84 mmol, 1.1 equiv) of CH_3SO_2Cl to give 277 mg (89%) of (20R)-20-(hydroxymethyl)-4α-methyl-5α-pregnane mesylate. The procedure of Partridge[19] was repeated using 277 mg (0.68 mmol) of (20R)-20-(hydroxymethyl)-4α-methyl-5α-pregnane mesylate and 977 mg (6.7 mmol, 10 equiv) of NaI to give 246 mg (84%) of **21b**: mp 136.5–138 °C; IR ($CHCl_3$) 2900, 1430, 1360 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.79 (d, J = 6.2 Hz, 3, C-4α CH_3), 0.96 (d, J = 6 Hz, 3, C-21 CH_3), 3.20–3.50 (m, 2, CH_2I); ^{13}C NMR ($CDCl_3$) δ 12.2 (C-18), 13.0 (C-19), 19.2, 20.4, 20.7, 21.3, 21.6, 23.7, 24.0, 27.7, 31.0, 32.0, 34.9, 36.3, 36.4, 36.6, 38.7, 39.8, 42.2, 53.3, 54.4, 54.6, 56.2. Anal. Calcd for $C_{23}H_{39}I$: C, 62.43; H, 8.88. Found: C, 62.51; H, 8.91.

(20*R*,22*E*,24*R*)-4-((Phenylthio)methyl)-4,22-stigmastadien-3-one (23). The procedure described for the preparation of **13** was repeated using 16.7 g (40.7 mmol) of (22*E*)-stigmasta-4,22-dien-3-one,[13] 1.66 g (10.9 mL, 105 mmol, 2.6 equiv) of thiophenol, 88 g (21.8 mL, 292 mmol, 7.2 equiv) of 37% formalin, and 8.7 g (12 mL, 86.3 mmol, 2.1 equiv) of Et_3N in 90 mL of EtOH at reflux for 72 h to afford an oil which crystallized upon storing at −5 °C for 2–3 days. The solid was recrystallized from 1:3 Et_2O–EtOH followed by a second recrystallization from 1:2 Et_2O–EtOH to yield 13.4 g (62%) of **23**: mp 92–93 °C; IR ($CHCl_3$) 1660 (C=O), 1595 (C=C) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.71 (s, 3, C-18 CH_3), 0.78–0.86 (m, 9, C-26, C-27, C-29 CH_3), 1.01 (d, J = 6.4 Hz, 3, C-21 CH_3), 1.14 (s, 3, C-19 CH_3), 3.87 (s, 2, CH_2SPh), 4.95–5.21 (m, 2, CH=CH), 7.18–7.40 (m, 5, ArH); ^{13}C NMR ($CDCl_3$) δ 11.8 (C-18), 11.9 (C-19), 17.5, 18.7, 20.7, 20.8 (two C), 23.8, 25.1, 27.9, 28.5, 28.6, 31.6, 31.7, 33.4, 34.5, 34.8, 39.1, 39.3, 40.2, 42.0, 51.0, 53.9, 55.6, 55.7, 126.5, 128.2, 128.7, 129.4, 131.0 (C-23), 136.6 (C-22), 138.2 (C-4), 168.4 (C-5), 197.2 (C=O). Anal. Calcd for $C_{36}H_{52}SO$: C, 81.14; H, 9.84. Found: C, 81.00; H, 9.86.

(20*R*,22*E*,24*R*)-4α-Methyl-5α-stigmast-22-en-3β-ol (24). The procedure described for the preparation of **14** was repeated using 7.9 g (14.8 mmol, 1 equiv) of **23** and 2.5 g (357 mmol, 3 equiv) of Li in 300 mL of NH_3 and using EtOH instead of NH_4Cl during the quenching process to afford 5.2 g (82%) of **24**: mp 92–93 °C; IR ($CHCl_3$) 3610 (OH), 980 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.67 (s, 3, C-18 CH_3), 0.79 (d, J = 6.4 Hz, 3, C-26 CH_3), 0.80 (t, J = 7 Hz, 3, C-29 CH_3), 0.83 (s, 3, C-19 CH_3), 0.84 (d, J = 6.4 Hz, 3, C-27 CH_3), 0.94 (d, J = 6.2 Hz, 3, C-4α CH_3), 1.00 (d, J = 6.4 Hz, 3, C-21 CH_3), 3.02–3.14 (m, 1, CHOH), 4.94–5.21 (m, 2, CH=CH);

^{13}C NMR ($CDCl_3$) δ 11.99 (C-18), 12.02 (C-19), 13.1, 14.9, 18.8, 20.9, 21.0, 23.96, 24.03, 25.2, 28.8, 30.8, 31.7, 32.0, 34.6, 35.8, 36.6, 39.0, 39.8, 40.4, 42.2, 50.8, 51.1, 54.4, 55.9, 56.5, 76.5 (CHOH), 128.7 (C-23), 138.0 (C-22). Anal. Calcd for $C_{30}H_{52}O$: C, 84.04; H, 12.23. Found: C, 84.11; H, 12.21.

(20*R*,22*E*,24*R*)-4α-Methyl-5α-stigmast-22-ene (25). The procedure of Robins[16c] was repeated using 12.5 g (29 mmol) of **24**, 6 g (35 mmol, 1.2 equiv) of phenyl thionochloroformate, and 11 g (38 mmol, 1.3 equiv) of n-Bu_3SnH to afford, after chromatography on silica gel using hexane and recrystallization from 1:1 EtOAc–EtOH, 9.8 g (81%) of **25**: mp 119–120 °C; ^{1}H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.75–0.92 (m, 15, C-4α, C-19, C-26, C-27, C-29 CH_3), 1.01 (d, J = 6.6 Hz, 3, C-21 CH_3), 4.93–5.22 (m, 2, CH=CH); ^{13}C NMR ($CDCl_3$) δ 12.7 (C-19), 13.7 (C-18), 19.4, 21.0, 21.4, 21.5, 21.6, 22.3, 23.1, 24.7, 25.9, 29.5, 30.2, 31.8, 32.4, 32.7, 35.6, 36.9, 37.0, 39.4, 40.6, 41.1, 42.8, 51.8, 54.0, 55.4, 56.6, 57.4, 129.9 (C-23), 139.3 (C-22). Anal. Calcd for $C_{30}H_{52}$: C, 87.30; H, 12.70. Found: C, 87.32; H, 12.67.

Methyl (20*R*,23ζ,24*S*)-4α-Methyl-5α-stigmastane-23-carboxylate (27). The procedure described for the preparation of **40e** and **40f** (vide infra) was repeated using 44 mg (0.1 mmol) of **21a** with 79 mg (0.5 mmol) of methyl (3*R*)-3-ethyl-4-methylpentanoate[11] (**26**) to afford 37 mg (78%) of **27a** and **27b** as a mixture: IR ($CHCl_3$) 1730 (C=O), 1460, 1430, 1360, 1165 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.62 and 0.64 (two s, 3, C-18 CH_3), 0.75–0.94 (m, 18, C-4α, C-19, C-21, C-26, C-27, C-29 CH_3), 2.48–2.60 (m, 1, C*H*CO_2CH_3); exact mass spectrum calcd for $C_{32}H_{54}O_2$ 472.4283, found 472.4285. GC analysis on an SE-30 fused silica gel capillary column (15 m) indicated that the product was a 3:1 ratio of **27a** and **27b**.

(20*R*,23ζ,24*S*)-4α-Methyl-5α-stigmastane-23-carboxylic Acid (28). To 35 mg (0.074 mmol) of **27** in 1 mL of collidine was added 99 mg (0.74 mmol, 10 equiv) of anhydrous LiI. The mixture was refluxed at 172 °C under N_2 for 12 h, cooled, diluted with 2 M HCl solution, and extracted with Et_2O. The combined organic solutions were washed with 10% $Na_2S_2O_3$ solution and dried over anhydrous $MgSO_4$. The product was chromatographed on silica gel using 1:10 EtOAc–hexane to afford 28 mg (82%) of **28**: ^{1}H NMR ($CDCl_3$) δ 0.64 (s, 3, C-18 CH_3), 0.72–0.92 (m, 18, C-4α, C-19, C-21, C-26, C-27, C-29 CH_3), 2.35–2.55 (m, 1, C*H*CO_2H); exact mass spectrum calcd for $C_{31}H_{52}O$ 458.4124, found 458.4129.

Phenylselenyl (20*R*,23ζ,24*S*)-4α-Methyl-5α-stigmastane-23-carboxylate (29). To a solution of 25 mg (0.054 mmol, 1 equiv) of **28** in 0.5 mL of anhydrous THF at 0 °C under N_2 was added 23 μL (16 mg, 0.162 mmol, 3 equiv) of anhydrous Et_3N and 16.1 μL (23 mg, 0.108 mmol, 2 equiv) of $PhOP(O)Cl_2$. After 30 min, an additional 37.5 μL (27 mmol, 5 equiv) of anhydrous Et_3N and 22.9 μL (34 mg, 0.216 mmol, 4 equiv) of benzeneselenol were added. After 30 min, the mixture was allowed to warm to 25 °C. The product was diluted with 1:1 hexane–Et_2O, washed twice with water and brine, and dried over anhydrous $MgSO_4$ to give a yellow oil that solidified at −5 °C. The crude selenoester was purified by column chromatography on silica gel using hexane followed by 5% EtOAc–hexane to afford 23 mg (69%) of **29**. This material was used directly in the next step without further purification.

(20*R*,24*R*)-4α-Methyl-5α-stigmastane (1) from 29. To a refluxing solution of 23 mg (0.038 mmol, 1 equiv) of **29** and 51 μL (55 mg, 0.91 mmol, 5 equiv) of (n-$Bu)_3SnH$ in 2 mL of anhydrous toluene under N_2 was added 0.6 mg (3.8 μmol, 0.1 equiv) of 2,2′-azobisisobutyronitrile. The solution was refluxed for 2 h, cooled, and concentrated. The product was treated with O_3 in 2 mL of hexane for 5 min at −78 °C. The solution was warmed to 25 °C and passed through a silica gel column. The hydrocarbon was eluted with hexane to afford 10 mg (62%) of **1** that was identical in all respects with **1** obtained from (22*E*)-stigmasterol (**22**) (vide infra).

(20*R*,24*R*)-4α-Methyl-5α-stigmastan-3β-ol (30). A mixture of 5 g (11.7 mmol) of **24** and 500 mg of 10% Pd–C in 150 mL of anhydrous benzene was hydrogenated at 60 psi and 25 °C for 48 h to afford 4.8 g (96%) of **30**: mp 184–185 °C; IR ($CHCl_3$) 3430 (OH) cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.65 (s, 3, C-18 CH_3), 0.81 (d, J = 6.8 Hz, 3, C-26 CH_3), 0.83 (s, 3, C-19 CH_3), 0.83 (d, J = 6.8 Hz, 3, C-27 CH_3), 0.84 (t, J = 7.2 Hz, 3, C-29 CH_3), 0.90 (d, J = 6.6 Hz, 3, C-21 CH_3), 0.95 (d, J = 6.4 Hz, 3, C-4α CH_3); ^{13}C NMR ($CDCl_3$) δ 11.7 (C-18), 11.8 (C-19), 13.1 (C-4), 14.9, 18.5, 18.8, 19.6, 20.9, 22.8, 24.0 (two C), 25.8, 28.1, 28.9, 30.9, 32.0, 33.7, 34.6, 35.8, 36.0, 36.6, 39.0, 39.9, 42.3, 45.6, 50.8, 54.4, 56.4, 76.5 (CHOH). Anal. Calcd for $C_{30}H_{54}O$: C, 83.65; H, 12.64. Found: C, 83.68; H, 12.82.

(20*R*,24*R*)-4α-Methyl-5α-stigmastane (1) from 30. The procedure of Robins[16c] was repeated using 4.3 g (10 mmol, 1 equiv) of **30** and 2.6 g (2.1 mL, 15 mmol, 1.5 equiv) of phenyl chlorothionoformate to afford 4.4 g (78%) of (20*R*,24*R*)-4α-methyl-5α-stigmastan-3β-ol phenyl thiocarbonate: mp 181–181.5 °C (from 2:1 EtOAc–EtOH); IR ($CHCl_3$) 1550, 1470, 1360 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.81 (d, J = 6.8 Hz, 3, C-26 CH_3), 0.83 (d, J = 6.8 Hz, 3, C-27 CH_3), 0.84 (t, J = 6.8 Hz, 3, C-29 CH_3), 0.88 (s, 3, C-19 CH_3), 0.91 (d, J = 7.2 Hz, 3, C-21 CH_3), 0.94 (d, J = 6.6 Hz, 3, C-4α CH_3), 4.85–4.98 (m, 1, C*H*OC(S)OPh); ^{13}C NMR ($CDCl_3$) δ 11.7 (C-18), 11.8 (C-19), 13.0 (C-4), 15.0, 18.5, 18.8, 19.6, 20.9, 22.8, 23.9, 24.0, 25.6, 25.8, 28.1, 28.9, 31.9, 33.7, 34.6, 35.7, 36.0, 36.1, 36.2, 39.8, 42.3, 45.6, 50.8, 54.2, 56.0, 56.3, 90.2 (*C*HOC(S)OPh), 122.2 (two C), 126.6, 129.6 (two C), 153.6, 195.3 (C=S). Anal. Calcd for $C_{37}H_{58}SO_2$: C, 78.39; H, 10.31. Found: C, 78.42; H, 10.27. The procedure of Robins[16c] was repeated using 4.3 g (7.7 mmol, 1 equiv) of (20*R*,24*R*)-4α-methyl-5α-stigmastan-3β-ol phenyl thiocarbonate and 3.4 g (3.1 mL, 11.6 mmol, 1.5 equiv) of (n-$Bu)_3SnH$ to afford 2.6 g (83%) of **1**: mp 92.5–93.5 °C (from 2:1 EtOAc–EtOH); IR ($CHCl_3$) 1450, 1440, 1360 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.65 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.80–0.88 (m, 12, C-4α, C-25, C-26, C-27 CH_3), 0.91 (d, J = 6.4 Hz, 3, C-21 CH_3); ^{13}C NMR ($CDCl_3$) δ 11.7 (C-18), 11.8 (C-19), 13.0 (C-4), 18.5, 18.8, 19.6, 20.4, 20.8, 21.7, 22.9, 24.0, 24.1, 25.9, 28.2, 28.9, 31.1, 32.1, 33.8, 34.9, 36.1, 36.3, 36.4, 38.7, 40.0, 42.0, 45.7, 53.4, 54.7, 56.1, 56.6. Anal. Calcd for $C_{30}H_{54}$: C, 86.88; H, 13.12. Found: C, 86.80; H, 13.04.

Methyl (2*E*)- and (2*Z*)-3,4-Dimethyl-2-pentenoate (32a) and (32b). The procedure of Huffman[25] was repeated using 4.32 g (109 mmol) of 60% NaOH solution, 20 g (108.5 mmol) of methyl dimethylphosphonoacetate, and 9.27 g (110 mmol) of 3-methyl-2-butanone in 290 mL of anhydrous 1,2-dimethoxyethane under N_2 to afford, after heating at 60 °C for 66 h, 8.83 g (58%) of **32** as a mixture of *E* and *Z* isomers: bp 105–108 °C (92 mm); IR ($CHCl_3$) 1730 (C=O), 1705 (C=C), 1465 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.00–1.12 (m, 6, $CH(CH_3)_2$), 1.80 and 2.14 (two d, J = 1 Hz, 3, $CHCH_3$, *E* and *Z* isomers), 2.25–2.50 (m, 1, C*H*$(CH_3)_2$), 3.67 and 3.69 (two s, 3, OCH_3, *E* and *Z* isomers), 5.58–5.62 and 5.67–5.71 (two m, 1, *E* and *Z* vinylic H); ^{13}C NMR ($CDCl_3$) δ 16.1, 19.0, 20.3, 20.6, 28.8, 37.9, 50.6, 113.2, 114.8, 166.2 (C=O), 167.9 (C=O). The *E*/*Z*-isomers were separated by the procedure of Pfaltz[24] using ether–pentane in place of EtOAc–hexane.

Methyl (3*S*)- or (3*R*)-3,4-Dimethylpentanoate (33a) and (33b). The procedure of Pfaltz[24] was repeated except diglyme was used as the solvent in place of *N*,*N*-dimethylformamide.

Methyl (2*S*,3*R*)- and (2*R*,3*R*)-3,4-Dimethyl-2-*n*-hexylpentanoate (34a) and (34b). The procedure described in the preparation of **40e** and **40f** was repeated using 21 mg (0.1 mmol, 1 equiv) of n-$C_6H_{13}I$ and 72 mg (0.5 mmol, 5 equiv) of methyl (3*S*)-3,4-dimethylpentanoate (**33a**) to afford 20 mg (86%) of methyl (2*S*,3*R*)- and (2*R*,3*R*)-3,4-dimethyl-2-*n*-hexylpentanoate (**34a**) and (**34b**): IR ($CHCl_3$) 1730 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.79–0.92 (m, 12, CH_3), 1.20–1.30 (m, 10, CH_2), 1.42–1.75 (m, 2, CH), 2.25–2.40 (m, 1, C*H*CO_2CH_3), 3.68 (s, 3, OCH_3); exact mass spectrum calcd for $C_{14}H_{25}O$ [M^+ − OCH_3] 197.1907, found 197.1921; calcd for $C_{11}H_{21}O_2$ [M^+ − C_3H_7] 185.1543, found 185.1542. The parent ion was too weak to obtain an exact mass measurement.

Methyl (2*R*,3*S*)- and (2*S*,3*S*)-3,4-Dimethyl-2-*n*-hexylpentanoate (34c) and (34d). The procedure described in the preparation of **40e and 40f** was repeated using 21 mg (0.1 mmol, 1 equiv) of *n*-$C_6H_{13}I$ and 72 mg (0.5 mmol, 5 equiv) of methyl (3*R*)-3,4-dimethylpentanoate (**33b**) to afford 19 mg (82%) of methyl (2*R*,3*S*)- and (2*S*,3*S*)-3,4-dimethyl-2-*n*-hexylpentanoate (**34c**) and (**34d**): IR ($CHCl_3$) 1730 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.79–0.92 (m, 12, CH_3), 1.20–1.30 (m, 10, CH_2), 1.42–1.75 (m, 2, CH), 2.25–2.40 (m, 1, C*H*CO_2CH_3), 3.68 (s, 3, OCH_3); exact mass spectrum calcd for $C_{14}H_{28}O_2$ [M^+] 228.2089, found 228.2091; calcd for $C_{14}H_{25}O$ [M^+ − OCH_3] 185.1543, found 185.1544.

Methyl (20*R*,23*S*)- and (20*R*,23*R*)-4α-Methyl-27-nor-5α-cholestane-23-carboxylate (37a) and (37b). The procedure

described for the preparation of **40e** and **40f** was repeated using 58 mg (0.5 mmol, 5 equiv) of methyl pentanoate (**35**) and 44 mg (0.1 mmol, 1 equiv) of **21a** to afford 23 mg (54%) of **37a** and **37b**: IR ($CHCl_3$) 1730 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.61 (s, 3, C-18 CH_3), 0.78 (s, 3, C-19 CH_3), 0.81 (d, J = 5 Hz, 3, C-4α CH_3), 0.89 (t, J = 8.4 Hz, 3, C-26 CH_3), 0.91 (d, J = 7.2 Hz, 3, C-21 CH_3), 2.41–2.53 (m, 1, C$H$$CO_2CH_3$), 3.66 (s, 3, CO_2CH_3); exact mass spectrum calcd for $C_{29}H_{50}O_2$ 430.3811 [M^+], found 430.3823; calcd for $^{13}C^{12}C_{28}H_{50}O_2$ [M^+ + 1] 431.3844, found 431.3843; calcd for $C_{27}H_{45}O_2$ [$M^+ - C_2H_5$] 401.3420, found 401.3420. GC analysis on an SE-30 fused silica gel capillary column (15 m) indicated that the product was a 5.1:1 ratio of **37a** and **37b**.

Methyl (20*S*,23*S*)- and (20*S*,23*R*)-4α-Methyl-27-nor-5α-cholestane-23-carboxylate (37c) and (37d). The procedure described for the preparation of **40e** and **40f** was repeated using 58 mg (0.5 mmol, 5 equiv) of methyl pentanoate (**35**) and 44 mg (0.1 mmol, 1 equiv) of **21b** to afford 22 mg (51%) of **37c** and **37d**: IR ($CHCl_3$) 1730 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.65 (s, 3, C-18 CH_3), 0.78 (s, 3, C-19 CH_3), 0.80 (d, J = 4.9 Hz, 3, C-4α CH_3), 0.88–0.92 (m, 6, C-21, C-26 CH_3), 2.33–2.58 (m, 1, C$H$$CO_2CH_3$), 3.66 (s, 3, CO_2CH_3); exact mass spectrum calcd for $C_{29}H_{50}O_2$ 430.3811 [M^+], found 430.3812. GC analysis on an SE-30 fused silica gel capillary column (15 m) indicated that the product was a 5.3:1 ratio of **37c** and **37d**.

Methyl (20*R*,23*S*)- and (20*R*,23*R*)-4α-Methyl-5α-cholestane-23-carboxylate (38a) and (38b). The procedure described for the preparation of **40e** and **40f** was repeated using 65 mg (0.5 mmol, 5 equiv) of methyl 4-methylpentanoate (**36**) and 44 mg (0.1 mmol, 1 equiv) of **21a** to afford 25 mg (58%) of **38a** and **38b**: IR ($CHCl_3$) 1730 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.62 (s, 3, C-18 CH_3), 0.78 (s, 3, C-19 CH_3), 0.81 (d, J = 5 Hz, 3, C-4α CH_3), 0.85 (d, J = 6.4 Hz, 6, C-26, C-27 CH_3), 0.91 (d, J = 7.2 Hz, 3, C-21 CH_3), 2.40–2.50 (m, 1, C$H$$CO_2CH_3$), 3.66 (s, 3, CO_2CH_3); exact mass spectrum calcd for $C_{30}H_{50}O_2$ [M^+] 444.3959, found 444.3951. GC analysis on an SE-30 fused silica gel capillary column (15 m) indicated that the product was a 6.6:1 ratio of **38a** and **38b**.

Methyl (20*R*,23*R*)- and (20*R*,23*S*)-4α-Methyl-24-methylene-5α-cholestane-23-carboxylate (39a) and (39b). The procedure described for the preparation of **40e** and **40f** was repeated using 71 mg (0.5 mmol, 5 equiv) of methyl 3,4-dimethyl-2-pentenoate (**32**; mixture of E/Z isomers) and 44 mg (0.1 mmol, 1 equiv) of **21a** to afford 35 mg (76%) of **39a** and **39b** that could not be separated by chromatography: IR ($CHCl_3$) 1730 (C=O), 890 (C=CH_2) cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.63 (s, 3, C-18 CH_3), 0.78 (s, 3, C-19 CH_3), 0.79 (d, J = 5 Hz, 3, C-4α CH_3), 0.92 (d, J = 6.5 Hz, 3, C-21 CH_3), 1.04 (d, J = 6.8 Hz, 6, C-26, C-27 CH_3), 3.10–3.21 (m, 1, C$H$$CO_2CH_3$), 3.66 (s, 3, CO_2CH_3), 4.88 and 4.94 (two s, 2, C=CH_2); exact mass spectrum calcd for $C_{31}H_{52}O_2$ [M^+] 456.3967, found 456.3973; calcd for $C_{30}H_{49}O_2$ [$M^+ - CH_3$] 441.3733, found 441.3743. GC analysis on an SE-30 fused silica gel capillary column (15 m) indicated that the product was a 2.4:1 ratio of **39a** and **39b**.

Methyl (20*S*,23*R*)- and (20*S*,23*S*)-4α-Methyl-24-methylene-5α-cholestane-23-carboxylate (39c) and (39d). The procedure described for the preparation of **40e** and **40f** was repeated using 71 mg (0.5 mmol, 5 equiv) of methyl 3,4-dimethyl-2-pentenoate (**32**; mixture of E/Z isomers) and 44 mg (0.1 mmol, 1 equiv) of **21b** to afford 33 mg (72%) of **39c** and **39d**: IR ($CHCl_3$) 1730 (C=O), 890 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.65 (s, 3, C-18 CH_3), 0.78 (s, 3, C-19 CH_3), 0.79 (d, J = 5 Hz, 3, C-4α CH_3), 0.92 (d, J = 6.4 Hz, 3, C-21 CH_3), 1.04 (d, J = 6.8 Hz, 6, C-26, C-27 CH_3), 3.08–3.18 (m, 1, C$H$$CO_2CH_3$), 3.65 (s, 3, CO_2CH_3), 4.93 and 4.99 (two s, 2, C=CH_2); exact mass spectrum calcd for $C_{31}H_{52}O_2$ [M^+] 456.3967, found 456.3978. GC analysis on an SE-30 fused silica gel capillary column (15 m) indicated that the product was a 2.2:1 ratio of **39c** and **39d**.

Methyl (20*R*,23*R*,24*S*)- and (20*R*,23*S*,24*S*)-4α,24-Dimethyl-5α-cholestane-23-carboxylate (40a) and (40b). The procedure described for the preparation of **40e** and **40f** was repeated using 44 mg (0.1 mmol) of **21a** with 72 mg (0.5 mmol) of **33b** to afford 38 mg (83%) of a mixture of **40a** and **40b** as an oil: IR ($CHCl_3$) 1730 (C=O), 1460, 1430, 1360, 1165 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.64 (s, 3, C-18 CH_3), 0.72–0.92 (m, 18, C-4α, C-19 and side-chain CH_3), 3.65 and 3.77 (two s, 3, OCH_3); exact mass spectrum calcd for $C_{30}H_{54}O_2$ 458.4124, found 458.4127. GC analysis on an SE-30 fused silica gel capillary column (15 m) indicated that the product was a 4:1 ratio of **40a** and **40b**.

Methyl (20*R*,23*R*,24*R*)- and (20*R*,23*S*,24*R*)-4α,24-Dimethyl-5α-cholestane-23-carboxylate (40e) and (40f). To a solution of 105 μL (76 mg, 0.75 mmol, 7.5 equiv) of diisopropylamine in 0.5 mL of anhydrous THF at −20 °C was added 200 μL (0.5 mmol, 5 equiv) of 2.5 M n-BuLi in hexane. The solution was stirred at −20 °C for 20 min and cooled to −78 °C. To this solution was added dropwise 72 mg (0.5 mmol, 5 equiv) of methyl (3*S*)-3,4-dimethylpentanoate (**33a**) in 0.5 mL of THF. The mixture was stirred at −78 °C for 30 min, and 44 mg (0.1 mmol, 1 equiv) of **21a** in 0.5 mL of THF and 87 μL (0.5 mmol, 5 equiv) of anhydrous $((CH_3)_2N)_3PO$ was added dropwise. The mixture was stirred at −78 °C for 4 h and was allowed to warm to 25 °C. The mixture was diluted with hexane and water and extracted with hexane. The combined organic extracts were washed successively with saturated NH_4Cl solution and brine and dried over anhydrous $MgSO_4$. The crude product was chromatographed on silica gel using 1:50 EtOAc–hexane to afford 37 mg (81%) of **40e** and **40f** as an oil: IR ($CHCl_3$) 1730 (C=O), 1460, 1435, 1370, 1160 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.63 (s, 3, C-18 CH_3), 0.75–0.93 (m, 18, C-4α, C-19, and side-chain CH_3), 3.64 and 3.65 (two s, 3, OCH_3); exact mass spectrum calcd for $C_{30}H_{54}O_2$ 458.4124, found 458.4115; calcd for [$M^+ - CH_3$] $C_{30}H_{51}O_2$ 443.3889, found 443.3881. GC analysis on an SE-30 fused silica gel capillary column (15 m) indicated that the product was a 1:4 ratio of **40e** and **40f**.

(20*R*,23*R*,24*S*)- and (20*R*,23*S*,24*S*)-5α-Dinosteran-29-ol (41a) and (41b). The reduction of a mixture of **40a** and **40b** with $LiAlH_4$ provided a mixture of **41a** and **41b**, respectively, that was separated by chromatography on silica gel using 1:10 EtOAc–hexane. The principal epimer **41a** had the following physical and spectral data: mp 162–164 °C; IR ($CHCl_3$) 3615, 1460, 1440, 1380 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.65 (s, 3, C-18 CH_3), 0.75 (d, J = 6.9 Hz, 3, C-28 CH_3), 0.78 (s, 3, C-19 CH_3), 0.79 (d, J = 6.4 Hz, 3, C-4α CH_3), 0.88 (d, J = 6.6 Hz, 3, C-21 CH_3), 0.92 (d, J = 6.4 Hz, 6, C-26 and C-27 CH_3), 3.56 (ddd, J_1 = 3.6 Hz, J_2 = 7.9 Hz, J_3 = 10 Hz, 2, CHCH_2OH); ^{13}C NMR ($CDCl_3$) δ 11.4, 12.1, 13.3, 18.8, 19.9, 20.6, 21.0, 21.6, 21.9, 24.1, 24.3, 28.8, 29.8, 31.3, 32.2, 32.7, 34.1, 35.1, 36.4, 36.6, 38.9 (two C), 39.0, 40.2, 42.6, 53.8, 54.8, 56.8, 57.3, 63.9 (CH_2OH); exact mass spectrum calcd for $C_{30}H_{54}O$ [M^+] 430.4175, found 430.4171. The minor epimer **41b** had the following physical and spectral data: mp 177–179 °C; IR ($CHCl_3$) 3615, 1460, 1440, 1380 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.66, (s, 3, C-18 CH_3), 0.75 (d, J = 7 Hz, 3, C-28 CH_3), 0.79 (d, J = 6.4 Hz, 3, C-4α CH_3), 0.79 (s, 3, C-19 CH_3), 0.89 (d, J = 6.6 Hz, 3, C-21 CH_3), 0.93 (d, J = 6.9 Hz, 6, C-26 and C-27 CH_3), 3.50 (ddd, J_1 = 4 Hz, J_2 = 8.5 Hz, J_3 = 10 Hz, 2, CH_2OH); ^{13}C NMR ($CDCl_3$) δ 11.8, 12.2, 13.3, 18.5, 20.5, 21.0, 21.1, 21.5, 21.9, 24.2, 24.3, 28.6, 31.1, 31.4, 32.3, 33.5, 35.2, 36.4, 36.5, 36.6, 38.8, 38.9, 39.5, 40.3, 42.7, 53.6, 54.9, 56.8, 57.4, 64.2 (CH_2OH); exact mass spectrum calcd for $C_{30}H_{54}O$ [M^+] 430.4175, found 430.4173.

(20*R*,23*R*,24*R*)- and (20*R*,23*S*,24*R*)-5α-Dinosteran-29-ol (41e) and (41f). The reduction of a mixture of **40e** and **40f** with $LiAlH_4$ provided a mixture of **41e** and **41f**, respectively, that was separated by chromatography on silica gel using 1:10 EtOAc–hexane. The principal epimer **41f** had the following physical and spectral data: mp 158–162 °C; IR ($CHCl_3$) 3615, 1460, 1440, 1380 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.65 (s, 3, C-18 CH_3), 0.79 (two d, J = 6.6 Hz, 6, C-4α, C-28 CH_3), 0.79 (s, 3, C-19 CH_3), 0.85 (d, J = 6.6 Hz, 3, C-21 CH_3), 0.92 (d, J = 6.6 Hz, 6, C-26, C-27 CH_3), 3.52 (d, J = 6.2 Hz, 2, CH_2OH); ^{13}C NMR ($CDCl_3$) δ 12.0 (two C), 13.3, 19.5, 19.7, 20.6, 21.0, 21.9, 22.3, 24.2, 24.3, 28.5, 29.4, 31.3, 32.2, 34.4, 35.1, 36.0, 36.4, 36.5, 38.8, 39.4, 40.2, 41.4, 42.5, 53.5, 54.7, 56.6, 57.8, 65.6 (CH_2OH); exact mass spectrum calcd for $C_{30}H_{54}O$ [M^+] 430.4175, found 430.4175. The minor epimer **41e** had the following physical and spectral data: mp 128–130 °C; IR ($CHCl_3$) 3615 (OH), 1460, 1440, 1380 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.78 (d, J = 6.6 Hz, 3, C-4α CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.3 Hz, 3, C-28 CH_3), 0.82 (d, J = 6.9 Hz, 3, C-21 CH_3), 0.91 (d, J = 6.4 Hz, 3, C-26 CH_3), 0.93 (d, J = 6.6 Hz, 3, C-27 CH_3), 3.64 (d, J = 2.8 Hz, 2 CH_2OH); ^{13}C NMR ($CDCl_3$) δ 11.7, 12.1, 13.2, 17.6, 18.8, 20.6, 21.0, 21.9, 22.1, 24.2, 24.3, 28.8, 28.9, 31.3, 32.2, 34.7, 35.1, 36.4, 36.5, 38.8, 39.9, 40.2, 40.9, 42.6, 53.5, 54.8, 56.8, 57.3, 62.8 (CH_2OH); exact mass spectrum calcd for $C_{30}H_{54}O$ [M^+] 430.4175, found 430.4177; calcd for $^{13}C^{12}C_{29}H_{54}O$ [M^+ + 1] 431.4208, found 431.4219; calcd for

$C_{29}H_{51}O$ [$M^+ - CH_3$] 415.3940, found 415.3949; calcd for $C_{28}H_{49}O$ [$M^+ - C_2H_5$] 401.3783, found 401.3782.

(20*R*,23*R*,24*S*)-5α-Dinosteran-29-ol Mesylate. The procedure of Crossland[18] was repeated using 118 mg (0.27 mmol) of **41a** and 65 mg (0.54 mmol, 2 equiv) of CH_3SO_2Cl to afford 129 mg (93%) of mesylate: mp 125.5–126.5 °C; IR ($CHCl_3$) 1460, 1440, 1360, 1340, 1170, 940, 830 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.65 (s, 3, C-18 CH_3), 0.76 (d, J = 6.8 Hz, C-28 CH_3), 0.77 (d, J = 6.3 Hz, C-4α CH_3), 0.78 (s, 3, C-19 CH_3), 0.87 (d, J = 6.6 Hz, 3, C-21 CH_3), 0.90 (d, J = 6.6 Hz, 3, C-26 CH_3), 0.92 (d, J = 6.3 Hz, 3, C-27 CH_3), 2.99 (s, 3, OSO_2CH_3), 4.12 (ddd, J_1 = 4.1 Hz, J_2 = 7.9 Hz, J_3 = 9.7 Hz, 2, $CH_2OSO_2CH_3$); ^{13}C NMR ($CDCl_3$) δ 11.3, 12.1, 13.2, 18.4, 19.8, 20.5, 20.9, 21.4, 21.8, 24.0, 24.2, 28.6, 29.6, 31.2, 32.2, 32.3, 33.8, 35.0, 36.0, 36.4, 36.5, 37.2, 38.8, 39.0, 40.1, 42.5, 53.4, 54.6, 56.7, 57.2, 70.9 ($CH_2OSO_2CH_3$).

(20*R*,23*S*,24*R*)-5α-Dinosteran-29-ol Mesylate. The procedure of Crossland[18] was repeated using 23 mg (0.05 mmol) of **41f** and 12 mg (0.1 mmol, 2 equiv) of CH_3SO_2Cl to afford 25 mg (93%) of mesylate: mp 154–155 °C; IR ($CHCl_3$) 1460, 1440, 1360, 1340, 1170, 940, 830 cm^{-1}; ^1H NMR ($CHCl_3$) δ 0.64 (s, 3, C-18 CH_3), 0.79 (d, J = 6.6 Hz, 3, C-4α CH_3), 0.79 (s, 3, C-19 CH_3), 0.81 (d, J = 6.6 Hz, 3, C-28 CH_3), 0.85 (d, J = 6.6 Hz, 3, C-21 CH_3), 0.92 (d, J = 6.6 Hz, 3, C-26 CH_3), 0.94 (d, J = 6.4 Hz, 3, C-27 CH_3), 3.00 (s, 3, SO_2CH_3), 4.10 (d, J = 6.5 Hz, 2, $CH_2OSO_2CH_3$); ^{13}C NMR ($CDCl_3$) δ 11.9, 12.0, 13.2, 19.3, 19.5, 20.6, 20.9, 21.9, 22.1, 24.1, 24.2, 28.5, 29.2, 31.3, 32.2, 34.0, 35.1, 36.0, 36.4, 36.5, 37.3, 38.5, 38.8, 39.4, 40.1, 42.6, 53.4, 54.7, 56.6, 57.6, 72.4 ($CH_2OSO_2CH_3$).

(20*R*,23*S*,24*R*)-5α-Dinosterane (2a). To 18 mg (0.47 mmol) of $LiAlH_4$ in 0.5 mL of anhydrous THF under N_2 was added 25 mg (0.049 mmol) of (20*R*,23*S*,24*R*)-5α-dinosteran-29-ol mesylate in 0.5 mL of THF. The mixture was refluxed for 5 h. The solution was cooled to 0 °C, quenched with water, and diluted with hexane. The organic solution was washed with brine and dried over anhydrous $MgSO_4$. The product was chromatographed on silica gel using hexane to afford 20 mg (96%) of **2a**: mp 106.5–107 °C; ^1H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.69 (d, J = 7.0 Hz, 3, C-28 CH_3), 0.69 (d, J = 6.5 Hz, 3, C-29 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.5 Hz, 3, C-4α CH_3), 0.87 (d, J = 6.5 Hz, 3, C-21 CH_3), 0.88 (d, J = 6.5 Hz, 3, C-27 CH_3), 0.89 (d, J = 6.4 Hz, 3, C-26 CH_3); ^{13}C NMR ($CDCl_3$) δ 12.0, 12.1, 13.3, 18.8, 20.1 (two C), 20.6, 21.0, 21.9, 22.6, 24.2, 24.3, 28.5, 28.6, 31.2, 32.2, 34.6, 35.1, 35.9, 36.4, 36.6, 38.8, 40.2, 40.6, 42.5, 44.0, 53.5, 54.8, 56.6, 57.9.

(20*R*,23*R*,24*S*)-5α-Dinosterane (2d). The procedure described for the preparation of **2a** was repeated using 90 mg (2.38 mmol) of $LiAlH_4$ in 1.3 mL of anhydrous THF and 129 mg (0.25 mmol) of the (20*R*,23*R*,24*S*)-5α-dinosteran-29-ol mesylate to afford, after chromatography on silica gel using hexane, 101 mg (96%) of **2d**: mp 129.5–130 °C; ^1H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.70 (d, J = 6.8 Hz, 3, C-29 CH_3), 0.72 (d, J = 6.8 Hz, 3, C-28 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.4 Hz, 3, C-4α CH_3), 0.81 (d, J = 6.8 Hz, 3, C-21 CH_3), 0.87 (d, J = 6.4 Hz, 3, C-27 CH_3), 0.88 (d, J = 6.8 Hz, 3, C-26 CH_3); ^{13}C NMR ($CDCl_3$) δ 11.4, 12.1, 13.3, 18.349, 18.381, 19.1, 20.6, 21.0, 21.8, 21.9, 24.1, 24.3, 28.6, 29.5, 31.28, 31.29, 32.2, 33.7, 35.1, 36.4, 36.6, 38.1, 38.8, 40.2, 42.6, 45.2, 53.5, 54.8, 56.8, 57.4.

(20*R*,23*R*)- and (20*R*,23*S*)-5α-Dinoster-24(28)-en-29-ol (42a) and (42b). To a solution of 32 mg (0.07 mmol) of a mixture of **39a** and **39b** in 3 mL of anhydrous THF was added 8 mg (0.21 mmol, 3 equiv) of $LiAlH_4$. The solution was stirred for 2 h and quenched with H_2O. The product was extracted with Et_2O, dried over anhydrous $MgSO_4$, and chromatographed on silica gel using 1:10 EtOAc–hexane to afford 21 mg (67%) of **42a** and 9 mg (29%) of **42b**. The epimer **42a** had the following spectral data: IR ($CHCl_3$) 3430 (OH), 890 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.79 (d, J = 6.3 Hz, 3, C-4α CH_3), 0.79 (s, 3, C-19 CH_3), 0.92 (d, J = 7.7 Hz, 3, C-21 CH_3), 1.06 (d, J = 7 Hz, 6, C-26, C-27 CH_3), 3.47–3.66 (m, 2, CH_2OH), 4.80 and 4.96 (two s, 2, C=CH_2); ^{13}C NMR ($CDCl_3$) δ 12.1 (C-18), 13.2 (C-19), 18.9, 20.6, 20.9, 21.9, 22.4, 22.5, 24.1, 24.2, 28.6, 31.3, 32.2, 33.7, 34.4, 35.1, 36.4, 36.5, 38.7, 38.8, 40.2, 42.6, 43.8, 53.5, 54.7, 56.7, 57.0, 63.7 (CH_2OH), 107.2 (C=CH_2), 158.4 (C=CH_2); exact mass spectrum calcd for $C_{30}H_{52}O$ [M^+] 428.4018, found 428.4019. The epimer **42b** had the following spectral data: IR ($CHCl_3$) 3430 (OH), 890 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.61 (s, 3, C-18 CH_3), 0.78 (s, 3, C-19 CH_3), 0.79 (d, J = 6.3 Hz, 3, C-4α CH_3), 0.91 (d, J = 6.3 Hz, 3, C-21 CH_3), 1.04 (d, J = 6.2 Hz, 6, C-26, C-27 CH_3), 3.39–3.55 (m, 2, CH_2OH), 4.82 and 5.01 (two s, 2, C=CH_2); ^{13}C NMR ($CDCl_3$) δ 11.1 (C-18), 12.4 (C-19), 17.9, 19.7, 20.1, 21.0, 21.6, 22.2, 23.3, 23.4, 27.6, 30.5, 31.4, 32.1, 32.6, 34.3, 35.6, 35.8, 36.7, 38.1, 39.4, 41.8, 44.5, 52.7, 54.0, 56.0, 66.8 (CH_2OH), 108.4 (C=CH_2), 156.1 (C=CH_2); exact mass spectrum calcd for $C_{30}H_{52}O$ [M^+] 428.4018, found 428.4013.

(20*R*,23*S*)-5α-Dinoster-24(28)-en-29-ol *tert*-Butyldimethylsilyl Ether. The procedure of Corey[30] was repeated using 38 mg (0.089 mmol) of **42b**, 59 mg (0.89 mmol, 10 equiv) of imidazole, and 68 mg (0.45 mmol, 5 equiv) of *tert*-butyldimethylsilyl chloride in 4 mL of *N*,*N*-dimethylformamide for 30 min at 60 °C to afford, after chromatography on silica gel using hexane, 47 mg (96%) of (20*R*,23*S*)-5α-dinoster-24(28)-en-29-ol *tert*-butyldimethylsilyl ether: mp 144–145 °C; IR ($CHCl_3$) 1460, 1440, 1380, 1250, 1050, 840 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.03 (s, 6, $Si(CH_3)_2$), 0.63 (s, 3, C-18 CH_3), 0.79 (d, J = 6.4 Hz, 3, C-4α CH_3), 0.79 (s, 3, C-19 CH_3), 0.88 (d, J = 8.1 Hz, 3, C-21 CH_3), 0.89 (s, 9, $C(CH_3)_3$), 1.01 (d, J = 6.5 Hz, 3, C-26 CH_3), 1.04 (d, J = 6.6 Hz, 3, C-27 CH_3), 3.37 (ddd, J_1 = 5.3 Hz, J_2 = 8 Hz, J_3 = 10 Hz, 2, CH_2OTBDMS), 4.68 (s, 1, vinylic H), 4.84 (s, 1, vinylic H); ^{13}C NMR ($CDCl_3$) δ −5.5 ($Si(CH_3)_2$), 12.0, 13.3, 18.3, 18.8, 20.6, 21.0, 21.9, 22.1, 22.5, 24.1, 24.3, 26.0 ($C(CH_3)_3$), 28.4, 31.3, 32.3, 33.2, 34.3, 35.1, 36.4, 36.6, 37.8, 38.9, 40.2, 42.5, 44.6, 53.5, 54.8, 56.8, 57.2, 68.4 (CH_2OTBDMS), 107.2 (C=CH_2), 157.1 (C=CH_2); exact mass spectrum calcd for $C_{32}H_{57}OSi$ 485.4179, found 485.4178.

(20*R*,23*R*)-5α-Dinoster-24(28)-en-29-ol *tert*-Butyldimethylsilyl Ether. The procedure of Corey[30] was repeated using 78 mg (0.18 mmol) of **42a**, 119 mg (1.8 mmol, 10 equiv) of imidazole, and 136 mg (0.9 mmol, 5 equiv) of *tert*-butyldimethylsilyl chloride in 8 mL of *N*,*N*-dimethylformamide for 30 min at 60 °C to afford, after chromatography on silica gel using hexane, 96 mg (96%) of (20*R*,23*R*)-5α-dinoster-24(28)-en-29-ol *tert*-butyldimethylsilyl ether: mp 130.5–131 °C; IR ($CHCl_3$) 1460, 1440, 1380, 1250, 1090, 840 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.03 (s, 6, $Si(CH_3)_2$), 0.65 (s, 3, C-18 CH_3), 0.78 (s, 3, C-19 CH_3), 0.79 (d, J = 6.3 Hz, 3, C-4α CH_3), 0.87 (s, 9, $C(CH_3)_3$), 0.92 (d, J = 6.4 Hz, 3, C-21 CH_3), 1.02 (d, J = 6.7 Hz, 3, C-26 and C-27 CH_3), 3.52 (d, J = 5.8 Hz, 2, CH_2OTBDMS), 4.70 (s, 1, vinylic H), 4.78 (s, 1, vinylic H); ^{13}C NMR ($CDCl_3$) δ −5.4 ($Si(CH_3)_2$) 12.1, 13.3, 18.2, 19.2, 20.6, 21.0, 21.9, 22.1, 22.2, 24.2, 24.3, 25.9 ($C(CH_3)_3$), 28.5, 31.3, 32.3, 34.67, 34.72, 35.1, 36.4, 36.6, 38.9, 40.0, 40.2, 42.6, 43.5, 53.5, 54.8, 56.7, 57.4, 66.8, (CH_2OTBDMS), 106.0 (C=CH_2), 159.5 (C=CH_2); exact mass spectrum calcd for $C_{32}H_{57}OSi$ 485.4179, found 485.4176.

(20*R*,23*R*,24*R*)- and (20*R*,23*R*,24*S*)-5α-Dinosteran-29-ol *tert*-Butyldimethylsilyl Ether. A mixture of 96 mg (0.22 mmol) of (20*R*,23*R*)-5α-dinoster-24(28)-en-29-ol *tert*-butyldimethylsilyl ether (prepared from **42a**) and 45 mg (0.2 mmol) of PtO_2 in 3 mL of hexane was hydrogenated at 60 psi for 3 h at 25 °C. The catalyst was removed by filtration, and the product was concentrated to afford 94 mg (98%) of a mixture of saturated TBDMS ethers, (20*R*,23*R*,24*R*)- and (20*R*,23*R*,24*S*)-5α-dinosteran-29-ol *tert*-butyldimethylsilyl ether. The mixture was chromatographed on silica gel using hexane to afford (20*R*,23*R*,24*R*)-5α-dinosteran-29-ol *tert*-butyldimethylsilyl ether as the principal isomer: mp 142–142.5 °C; IR ($CHCl_3$) 1465, 1375, 1250, 1090, 840 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.02 (s, 6, $Si(CH_3)_2$), 0.65 (s, 3, C-18 CH_3), 0.76 (d, J = 6.6 Hz, 3, C-28 CH_3), 0.77 (d, J = 6.6 Hz, 3, C-4α CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 8.1 Hz, 3, C-21 CH_3), 0.88 (s, 9, $SiC(CH_3)_3$), 0.88 (d, J = 6.4 Hz, 3, C-26 CH_3), 0.89 (d, J = 6.6 Hz, 3, C-27 CH_3), 3.70 (ddd, J_1 = 4 Hz, J_2 = 3.8 Hz, J_3 = 10 Hz, 2, CH_2OTBDMS); ^{13}C NMR ($CDCl_3$) δ −5.54 ($SiCH_3$), −5.49 ($SiCH_3$), 11.7, 12.2, 13.3, 18.0, 18.2, 18.8, 20.6, 21.0, 21.9, 22.2, 24.2, 24.3, 25.9 ($C(CH_3)_3$), 28.5, 29.0, 31.3, 32.3, 34.3, 35.1, 36.5, 36.6, 36.9, 38.9, 39.6, 40.3, 41.3, 42.6, 53.5, 54.8, 56.8, 57.5, 62.4 (CH_2OTBDMS). The minor isomer, (20*R*,23*R*,24*S*)-5α-dinosteran-29-ol *tert*-butyldimethylsilyl ether, had the following physical and spectral data: mp 144.5–145 °C; IR ($CHCl_3$) 1460, 1380, 1250, 1090, 840 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.03 (s, 6, $Si(CH_3)_2$), 0.65 (s, 3, C-18 CH_3), 0.70 (d, J = 6.7 Hz, 3, C-28 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.3 Hz, 3, C-4α CH_3), 0.84 (d, J = 6.6 Hz, 3, C-21 CH_3), 0.86–0.92 (m, 6, C-26 and C-27 CH_3), 0.88 (s, 9, $SiC(CH_3)_3$), 3.47 (ddd, J_1 = 4 Hz, J_2 = 7 Hz, J_3 = 10

(30) Corey, E. J.; Venkateswarlu, A. *J. Am. Chem. Soc.* **1972**, *94*, 6190.

Hz, 2, CH_2OTBDMS); ^{13}C NMR ($CDCl_3$) δ -5.6 (SiCH_3), 11.3, 12.0, 13.1, 18.1, 18.7, 19.6, 20.5, 20.9, 21.6, 21.8, 24.0, 24.2, 25.8 (C(CH_3)$_3$), 28.6, 29.6, 31.2, 32.2, 33.0, 33.9, 35.0, 36.4, 36.5, 38.8 (two C), 39.0, 40.2, 42.5, 53.5, 54.8, 57.5, 64.0 (CH_2OTBDMS); exact mass spectrum calcd for $C_{32}H_{59}OSi$ 487.4335, found 487.4337.

(20*R*,23*S*,24*S*)- and (20*R*,23*S*,24*R*)-5α-Dinosteran-29-ol *tert*-Butyldimethylsilyl Ether. A mixture of 47 mg (0.086 mmol) of (20*R*,23*S*)-5α-dinoster-24(28)-en-29-ol *tert*-butyldimethylsilyl ether (prepared from **42b**) and 23 mg (0.1 mmol) of PtO_2 was hydrogenated in 2 mL of hexane at 60 psi for 3 h at 25 °C. The catalyst was removed by filtration, and the product was concentrated to afford 47 mg (100%) of a mixture of saturated TBDMS ethers, (20*R*,23*S*,24*S*)- and (20*R*,23*S*,24*R*)-5α-dinosteran-29-ol *tert*-butyldimethylsilyl ether. This mixture was not separable by chromatography on silica gel and was used directly in the deprotection step described below.

(20*R*,23*R*,24*R*)-5α-Dinosteran-29-ol (41e). To a solution of 69 mg (0.13 mmol) of (20*R*,23*R*,24*R*)-5α-dinosteran-29-ol *tert*-butyldimethylsilyl ether in 5 mL of THF was added 278 μL (0.38 mmol, 3 equiv) of 1 M (n-Bu)$_4$NF in THF. The solution was allowed to stir for 24 h at 25 °C and was diluted with EtOAc. The solution was washed with water and brine and dried over anhydrous $MgSO_4$. The product was chromatographed on silica gel using 1:10 EtOAc–hexane to afford 51 mg (95%) of **41e** having spectral data in agreement with that reported in the preparation of **41e** from **40e** (vide supra).

(20*R*,23*S*,24*S*)-5α-Dinosteran-29-ol (41b). The procedure described for the preparation of **41e** was repeated using 47 mg (0.09 mmol) of an inseparable mixture of (20*R*,23*S*,24*S*)- and (20*R*,23*S*,24*R*)-5α-dinosteran-29-ol *tert*-butyldimethylsilyl ethers and 257 μL (0.26 mmol, 3 equiv) of 1 M (n-Bu)$_4$NF in 4 mL of THF to afford, after chromatography on silica gel using 1:10 EtOAc–hexane, 35 mg (94%) of **41b** and **41f**, respectively. This mixture was separated by HPLC on Beckman C_{18} reversed-phase column using 2:10:100 water–EtOAc–MeOH to give a pure sample of **41b** having spectral data in agreement with that reported in the preparation of **41b** from **40b** (vide supra).

(20*R*,23*R*,24*R*)-5α-Dinosteran-29-ol Mesylate. The procedure of Crossland[18] was repeated using 51 mg (0.12 mmol) of **41e** and 27 mg (0.23 mmol, 2 equiv) of CH_3SO_2Cl to afford 59 mg (98%) of (20*R*,23*R*,24*R*)-5α-dinosteran-29-ol mesylate: mp 116–116.5 °C; IR ($CHCl_3$) 1460, 1440, 1360, 1170, 970, 940, 830 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.5 Hz, 6, C-4α and C-28 CH_3), 0.83 (d, J = 8.1 Hz, 3, C-21 CH_3), 0.91 (d, J = 6.3 Hz, 3, C-26 CH_3), 0.93 (d, J = 6.7 Hz, 3, C-27 CH_3), 2.99 (s, 3, $CH_2OSO_2CH_3$), 4.20 (ddd, J_1 = 4.5 Hz, J_2 = 4 Hz, J_3 = 10 Hz, 2, $CH_2OSO_2CH_3$); ^{13}C NMR ($CDCl_3$) δ 11.6, 12.1, 13.2, 17.8, 18.6, 20.6, 20.9, 21.9 (two C), 24.1, 24.2, 28.5, 29.0, 31.2, 32.2, 34.2, 35.0, 36.4, 36.5 (two C), 37.17, 37.24, 38.8, 40.2, 41.1, 42.6, 53.4, 54.7, 56.7, 57.2, 70.1 ($CH_2OSO_2CH_3$).

(20*R*,23*S*,24*S*)-5α-Dinosteran-29-ol Mesylate. The procedure of Crossland[18] was repeated using 25 mg (0.06 mmol) of **41b** and 13 mg (0.11 mmol, 2 equiv) of CH_3SO_2Cl to afford 29 mg (99%) of (20*R*,23*S*,24*S*)-5α-dinosteran-29-ol mesylate: mp 151–152 °C; IR ($CHCl_3$) 1460, 1440, 1360, 1340, 1170, 940, 830 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.6 Hz, 6, C-4α CH_3 and C-28 CH_3), 0.84–0.95 (m, 9, C-21, C-26 and C-27 CH_3), 3.00 (s, 3, $CH_2OSO_2CH_3$), 4.08 (septet, J_1 = 2 Hz, J_2 = 9 Hz, J_3 = 11 Hz, 2, $CH_2OSO_2CH_3$); ^{13}C NMR ($CDCl_3$) δ 11.7, 12.1, 13.3, 18.2, 20.6, 21.0, 21.3, 21.9, 24.1, 24.2, 28.7, 31.0, 31.3, 33.3, 35.0, 35.6, 35.9, 36.4, 36.5, 37.2, 38.8, 39.0, 40.2, 42.6, 53.4, 54.7, 56.7, 57.0, 71.7 ($CH_2OSO_2CH_3$).

(20*R*,23*R*,24*R*)-5α-Dinosterane (2b). The procedure described for the preparation of **2a** was repeated using 35 mg (0.92 mmol) of $LiAlH_4$ in 0.5 mL of anhydrous THF and 50 mg (0.098 mmol) of (20*R*,23*R*,24*R*)-5α-dinosteran-29-ol mesylate to afford, after chromatography on silica gel using hexane, 38 mg (94%) of **2b**: mp 143.5–144 °C; ^{1}H NMR ($CDCl_3$) δ 0.65 (s, 3, C-18 CH_3), 0.76 (d, J = 6.8 Hz, 3, C-28 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.4 Hz, 3, C-4α CH_3), 0.79 (d, J = 6.7 Hz, 3, C-21 CH_3), 0.87 (d, J = 6.7 Hz, 3, C-27 CH_3), 0.89 (d, J = 6.8 Hz, 3, C-26 CH_3), 0.92 (d, J = 6.8 Hz, 3, C-29 CH_3); ^{13}C NMR ($CDCl_3$) δ 11.4, 12.1, 13.3, 14.2, 18.7, 19.4, 20.6, 21.0, 21.7, 21.9, 24.2, 24.3, 28.6, 30.1, 31.2, 31.3, 32.3, 34.1, 35.1, 36.4, 36.6, 38.9, 40.2, 42.6, 42.8, 45.3, 53.5, 54.8, 56.8, 57.3.

(20*R*,23*S*,24*S*)-5α-Dinosterane (2c). The procedure described for the preparation of **2a** was repeated using 18 mg (0.47 mmol) of $LiAlH_4$ in 0.5 mL of anhydrous THF and 25 mg (0.049 mmol) of (20*R*,23*S*,24*S*)-5α-dinosteran-29-ol mesylate to afford, after chromatography on silica gel using hexane, 19 mg (93%) of **2c**: mp 161.5–162.5 °C; ^{1}H NMR ($CDCl_3$) δ 0.66 (s, 3, C-18 CH_3), 0.72 (d, J = 6.8 Hz, 3, C-28 CH_3), 0.79 (s, 3, C-19 CH_3), 0.79 (d, J = 6.3 Hz, 3, C-4α CH_3), 0.81 (d, J = 6.8 Hz, 3, C-29 CH_3), 0.81 (d, J = 6.8 Hz, 3, C-27 CH_3), 0.87 (d, J = 6.4 Hz, 3, C-21 CH_3), 0.88 (d, J = 6.8 Hz, 3, C-26 CH_3); ^{13}C NMR ($CDCl_3$) δ 10.6, 12.1, 13.3, 15.2, 18.5, 20.6, 21.0, 21.2, 21.5, 21.9, 24.2, 24.3, 28.5, 29.6, 31.0, 31.3, 32.2, 33.3, 35.1, 36.4, 36.6, 38.8, 40.1, 40.2, 42.0, 42.6, 53.5, 54.8, 56.7, 57.4.

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Supplementary Material Available: ^{1}H and ^{13}C NMR spectra for (20*S*)-20-(hydroxymethyl)-4α-methyl-5α-pregnane (**20a**), (20*R*)-20-(hydroxymethyl)-4α-methyl-5α-pregnane (**20b**), mesylate of (20*R*,23*R*,24*S*)-5α-dinosteran-29-ol (**41a**), mesylate of (20*R*,23*S*,24*S*)-5α-dinosteran-29-ol (**41b**), mesylate of (20*R*,23*R*,24*R*)-5α-dinosteran-29-ol (**41e**), mesylate of (20*R*,23*S*,24*R*)-5α-dinosteran-29-ol (**41f**), *tert*-butyldimethylsilyl ether of (20*R*,23*S*,24*S*)-5α-dinosteran-29-ol (**41b**) (^{1}H NMR only), *tert*-butyldimethylsilyl ether of (20*R*,23*R*,24*R*)-5α-dinosteran-29-ol (**41e**), (20*R*,23*S*,24*R*)-5α-dinosterane (**2a**), (20*R*,23*R*,24*R*)-5α-dinosterane (**2b**), (20*R*,23*S*,24*S*)-5α-dinosterane (**2c**), and (20*R*,23*R*,24*S*)-5α-dinosterane (**2d**) (23 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.