3β-Acetoxy-5β,6β-epoxy-19a-methylcholestane (5).—A suspension of 1.0 g of the diol **4** and 300 mg of *p*-toluenesulfonic acid in 50 ml of acetic anhydride was heated at 110° for 30 min. After cooling, the mixture was poured onto ice and extracted with ether. The ethereal extract was washed with sodium bicarbonate solution and water until neutral, dried, and evaporated *in vacuo*. The residue in 50 ml of ethanol was heated under reflux with 1.5 g of potassium hydroxide for 30 min, and the resulting epoxide was acetylated with pyridine and acetic anhydride. The crude product was chromatographed on alumina and elution with *n*-hexane–chloroform afforded 850 mg of the β-oxide **5**, which was recrystallized from methanol: mp 68°; $[\alpha]^{25}D$ −9° (*c* 0.439, $CHCl_3$); ir (KBr) 1745, 1239, 1040, 820 cm^{-1}; nmr ($CDCl_3$) δ 1.22 (19a-CH_3, t, J = 4 cps), 2.05 (3-OAc), 2.95 (6-H).

Anal. Calcd for $C_{30}H_{50}O_3$: C, 78.55; H, 10.99. Found: C, 78.75; H, 11.06.

3β-Acetoxy-5α-bromo-6β-hydroxy-19a-methylcholestane (6).—A solution of 700 mg of **5** in 70 ml of acetic acid and 0.21 ml of 47% hydrobromic acid was allowed to stand at room temperature for 30 min. The solution was diluted with water and then extracted with ether. The ether layer was washed with sodium bicarbonate solution and water, dried, and evaporated *in vacuo* below 30°. The residue was recrystallized from *n*-hexane–ether, and 550 mg of **6** was obtained: mp 134–135° dec; ir (KBr) 3490, 1725, 1260, 1040, 760 cm^{-1}.

Anal. Calcd for $C_{30}H_{51}O_3Br$: C, 66.77; H, 9.53. Found: C, 66.57; H, 9.75.

Oxidation of 6 with Lead Tetraacetate.—A suspension of 2.0 g of lead tetraacetate and 950 mg of calcium carbonate in 40 ml of cyclohexane was stirred and heated to 80°; then 350 mg of **6** and 400 mg of iodine was added. The mixture was irradiated with a 500-W lamp under reflux with vigorous agitation for 45 min. After the solution had become colorless, it was filtered, and the filtrate was washed with a 10% sodium thiosulfate solution and water. After evaporation of the solvent, the residue was chromatographed on alumina, and elution with *n*-hexane–chloroform (40:1) gave 70 mg of **8**. Further elution with the same solvent gave 159 mg of **7**. The products were recrystallized from methanol.

3β-Acetoxy-5α-bromo-6β,19*R*-epoxy-19a-methylcholestane (7): mp 124–125°; $[\alpha]^{25}D$ −3.0° (*c* 0.330, $CHCl_3$); ir (KBr) 1743, 1235, 1035, 790 cm^{-1}; nmr ($CDCl_3$) δ 1.47 (19a-CH_3, d, J = 7.5 cps), 2.05 (3-OAc), 4.1 (6-H), 4.58 (19-H, q, J = 7.5 cps), 5.2 (3-H).

Anal. Calcd for $C_{30}H_{49}O_3Br$: C, 67.00; H, 9.19. Found: C, 67.05; H, 9.49.

3β-Acetoxy-5α-bromo-6β,19*S*-epoxy-19a-methylcholestane (8): mp 146°; $[\alpha]^{25}D$ +17° (*c* 0.215, $CHCl_3$); ir (KBr) 1747, 1238, 1040, 920, 790 cm^{-1}; nmr ($CDCl_3$) δ 1.44 (19a-CH_3, d, J = 7 cps), 2.02 (3-OAc), 4.05 (6-H), 4.4 (19-H, q, J = 7 cps), 5.35 (3-H).

Anal. Calcd for $C_{30}H_{49}O_3Br$: C, 67.00; H, 9.19. Found: C, 66.79; H, 8.89.

3β-Acetoxy-19*R*-hydroxy-19a-methylcholest-5-ene (9b).—A solution of 150 mg of **7** in 5 ml of acetic acid and 0.2 ml of water was treated with 900 mg of zinc dust at 50° under vigorous stirring. The usual work-up gave crude **9b** and recrystallization from methanol afforded a pure sample (120 mg): mp 93–94°; $[\alpha]^{25}D$ −30° (*c* 0.266, $CHCl_3$); ir (KBr) 3520, 1745, 1240, 1035, 910 cm^{-1}; nmr ($CDCl_3$) δ 1.35 (19a-CH_3, d, J = 7.5 cps), 2.00 (3-OAc), 4.2 (19-H, q, J = 7.5 cps), 4.5 (3-H), 5.6 (6-H).

Anal. Calcd for $C_{30}H_{50}O_3$: C, 78.55; H, 10.99. Found: C, 78.32; H, 10.85.

3β-Acetoxy-19*S*-hydroxy-19a-methylcholest-5-ene (10b).—Reduction of 60 mg of **8** in the same way followed by recrystallization from methanol gave 40 mg of pure **10b**: mp 89°; $[\alpha]^{25}D$ −37° (*c* 0.784, $CHCl_3$); ir (KBr) 3510, 1740, 1245, 1040, 910 cm^{-1}; nmr ($CDCl_3$) δ 1.36 (19a-CH_3, d, J = 7 cps), 2.02 (3-OAc), 4.28 (19-H, q, J = 7 cps), 4.6 (3-H), 5.6 (6-H).

Anal. Calcd for $C_{30}H_{50}O_3$: C, 78.55; H, 10.99. Found: C, 78.24; H, 10.88.

3β-Acetoxy-19a-methyl-19-oxocholest-5-ene (11). Oxidation of 9b and 10b with Chromic Acid.—A solution of 125 mg of **9b** in 10 ml of acetone was treated with 0.1 ml of 8 *N* chromic sulfuric acid solution at 0° for 30 min. Treatment in the usual way gave the 19-oxo compound **11**, and its ir spectrum was identical with that of an authentic sample synthesized by another route and a mixture melting point was not depressed. Oxidation of **10b** in the same way also gave the same 19-oxo compound: mp 127–128°; $[\alpha]^{25}D$ −115° (*c* 0.665, $CHCl_3$); ir (KBr); 1742, 1705, 1240 cm^{-1}; nmr ($CDCl_3$) δ 2.00 (3-OAc), 2.18 (10-acetyl), 5.8 (6-H).

Anal. Calcd for $C_{30}H_{48}O_3$: C, 78.89; H, 10.59. Found: C, 78.81; H, 10.25.

Dehydration of 9b and 10b with Phosphorus Oxychloride.—A solution of 20 mg of **9b** in 0.5 ml of pyridine was treated with 0.05 ml of phosphorous oxychloride at room temperature overnight. Recrystallization of the crude product (18 mg) gave the pure 19a-methylene compound **2**, which was identical with an authentic sample prepared by the Wittig reaction. Dehydration of **10b** yielded the same compound **2** as that of **9b**.

Registry No.—**2b**, 24183-24-2; **3**, 29751-52-8; **4**, 29751-53-9; **5**, 29751-54-0; **6**, 29751-55-1; **7**, 29875-95-4; **8**, 29875-96-5; **9b**, 29875-97-6; **10b**, 29751-56-2; **11**, 24177-47-7.

Stereochemistry of the Isolongifolene Ketone Epimers

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Recently Dev[1] has reported that BF_3 etherate treatment of an isolongifolene epoxide[2] gives rise to a ketone to which he has assigned the stereochemistry as depicted in structure II. Epimerization of this ketone gives rise to a new ketone to which structure IV has been assigned. However, Eschinasi and coworkers[3] have assigned the opposite stereochemistry of these two ketones at the C-7 position. Described here is chemical evidence which supports Dev's assignment of the stereochemistry of these two epimeric ketones.

We have previously reported that acid treatment of isolongifolene epoxide I gave, among other products, rearranged alcohol III and ketone II.[4] Subsequent treatment of ketone II with base gave a more stable ketone IV. In order to establish the relative stereochemistry of these ketones at the C-7 position, the following approach was taken.

The lithium aluminum hydride reduction of ketone II gave alcohol V, which was refluxed with lead tetraacetate in benzene to give a cyclic ether VI in 60% yield. In contrast to this behavior, no detectable amount of cyclic ether was obtained by a similar lead tetraacetate treatment of alcohol VII which was obtained by the lithium aluminum hydride reduction of ketone IV (Scheme I).

When the stereochemistry of the hydroxyl group with regard to hydrogen at the C-7 position is cis, Dreiding models reveal that a cyclic ether cannot arise from VII; and, indeed, this was found to be the case. The possibility of the hydroxyl group having the opposite configuration is ruled out as Dreiding models indicate that a cyclic ether could be obtained from a compound with such structure. The assigned cis stereochemistry of the

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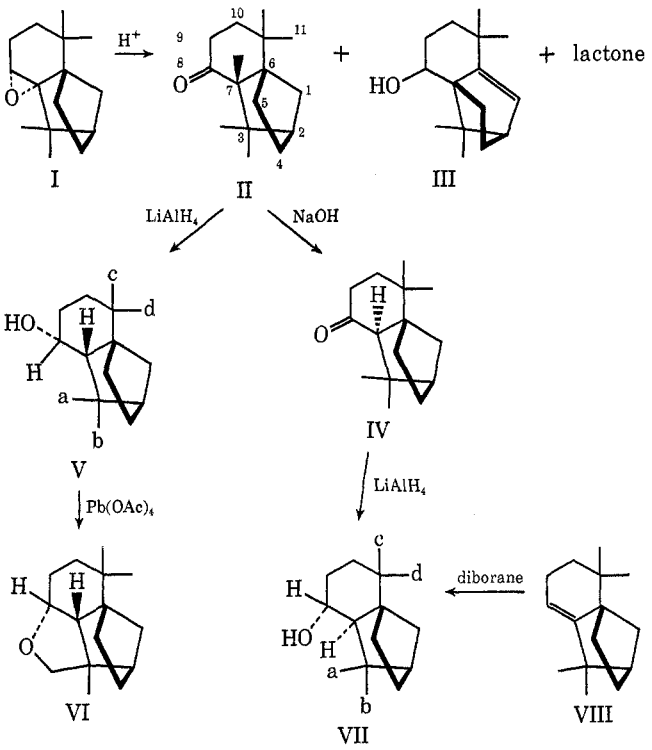
SCHEME I



alcohol VII is further supported by the fact that hydroboration[5] of the isolongifolene VIII gave a compound which was identical in all respects with alcohol VII, mp 124–126° (lit.[5] 122°).

The formation of VII by hydroboration could be attributed to the fact that diborane would preferably attack from the least hindered α side. The stereochemistry of the hydroxyl group at C-8 of alcohols V and VII is further supported by applying the nmr europium complexing technique described by Hinckley[6] and Williams.[7]

We conclude from these results that the more stable epimeric ketone has stereochemistry at C-7, as depicted in structure IV, and the less stable epimer has stereochemistry as shown in structure II. Thus the stereochemistry of the above two ketones and isolongifolene epoxide has been rightly assigned by Dev.[1]

Experimental Section[8]

Isolongifolene Alcohol V.—In a three-necked flask fitted with a condenser, stirrer, and addition funnel were placed 400 ml of dry tetrahydrofuran and 8.2 g (0.215 mol) of lithium aluminum hydride. A solution containing 91 g (0.41 mol) of the isolongifolene ketone II in 100 ml of dry tetrahydrofuran was added dropwise during 45 min to the above mixture. After the addition was over, the mixture was refluxed for 9 hr. The reaction mixture was cooled and 8 ml of water was added slowly followed by 8 ml of 15% sodium hydroxide followed by 24 ml of water. The crude mixture was filtered and the solvent was removed under vacuum. The crude oil was distilled to give a colorless oil: bp 114° (2 mm) (80% yield); infrared (Nujol) λ_{max} 2.94 (OH); nmr ($CDCl_3$) 0.93 $\left(6\text{ H, s, C}<^{CH_3}_{CH_3}\right)$, 1.02 (3 H, s, CCH_3), 1.12 (3 H, s, CCH_3), 1.2–1.73 (12 H, m, CH, CH_2), 4.15 (1 H, broad m, CHOH).

Anal. Calcd for $C_{15}H_{26}O$: C, 81.02; H, 10.98. Found: C, 81.58; H, 11.71.

Isolongifolene Cyclic Ether VI.—In a three-necked flask fitted with stirrer, thermometer, and reflux condenser were placed 11.0 g (0.025 mol) of lead tetraacetate, 5 g of calcium carbonate, and 185 ml of dry benzene. The mixture was refluxed for 1 hr and then 5.5 g (0.025 mol) of isolongifolene alcohol III was added and the mixture was refluxed for 22 hr. It was then cooled to 25°, 10 ml of ethylene glycol was added, and the mixture was heated to 80° for 1 hr. The mixture was then cooled, the solids were filtered off, and the filtrate was washed twice with 25 ml os 1% sodium hydroxide. The combined aqueous layers were extracted twice with ether and the organic layers were combined and dried over magnesium sulfate. The solvent was removed under vacuum. The crude product was distilled to give colorless liquid: bp 100° (0.2 mm) (60% yield); infrared (film) shows no hydroxyl band at 2.93 μ; nmr ($CDCl_3$) 0.95 (3 H, s, CCH_3), 0.99, 1.00 $\left(6\text{ H, s, C}<^{CH_3}_{CH_3}\right)$, 1.08–1.8 (11 H, m, CH_2, CH), 4.15–3.88 (3 H, m, $HCOCH_2$).

Anal. Calcd for $C_{15}H_{24}O$: C, 81.76; H, 10.98. Found: C, 81.48; H, 10.95.

Isolongifolene Alcohol VII.—The lithium aluminum hydride reduction of ketone IV, under the similar conditions as described for alcohol V, gave alcohol VII, mp 124–126°, as a major product in 60% yield. It was found to be identical in all respects with the one obtained by the hydroboration of isolongifolene (Table I).

TABLE I

NMR SPECTRAL DATA OF ALCOHOLS V AND VII COMPLEXES WITH Eu(DPM)$_3$[a]

	Alcohol V		Alcohol VII	
	Δ[Eu-(DPM)$_3$]	R, Å	Δ[Eu-(DPM)$_3$]	R, Å
(a) H_3C–C	2.06	2.5	2.27	3.0
(b) H_3C–C–	0.77	4.0	1.60	3.4
(c) H_3C C–	0.77	4.7	1.04	5.1
(d) CH_3 C–	0.60	4.80	0.64	5.4
HC–O–	4.86	1.35	6.06	1.35

[a] Log-log plot of Δ(Eu) *vs.* R (Å) gives best fit for the configurations assigned to the alcohols V and VII.

Registry No.—II, 29641-13-0; IV, 29461-14-1; V, 30469-89-7; VI, 30545-64-3; VII, 30469-90-0.

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Selenomethionine, a Potential Catalytic Antioxidant in Biological Systems[1,2]

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This report describes the first isolation and characterization of products resulting from the oxidation of sel-

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(2) The following abbreviations have been adopted: Z = $C_6H_5CH_2$-OCO; AcOH = acetic acid; MeOH = methanol; EtOAc = ethyl acetate.