

Synthesis of *S*-Methyl 2-Hydroxyalkanethioates, 2-Hydroxyalkanoic Acids and Related Compounds via the Addition Reaction of Tris(methylthio)methanide Ion to Alkanals

Kazuhiko ORITO,* Yoshikatsu SEKI, Hiroshi SUGINOME, and Tsukasa IWADARE†

Department of Chemical Process Engineering, Hokkaido University, Sapporo 060

†Research Laboratory, Sakura Finetechnical Co., Ltd., 3-1-8, Hikawadai, Nerima-ku, Tokyo 176

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In connection with the studies on biological activities on myrmicacin and related compounds, the synthetic method for 2-hydroxyalkanoic acids and the corresponding 1,2-diols was studied. The addition reaction of tris(methylthio)methylithium to the aldehydes (propanal—dodecanal) gave the corresponding 1,1,1-tris(methylthio)-2-alkanols **1a—j**. Treatment of **1** with mercury(II) chloride–mercury(II) oxide in water–acetone afforded *S*-methyl 2-hydroxyalkanethioates **2a—j**, and in methanol methyl 2-hydroxyalkanoates **3c—j** were obtained. Reduction of the thioates **2** with lithium aluminium hydride gave 1,2-diols **4c—j** and saponification produced the corresponding 2-hydroxyalkanoic acids **5c—j**.

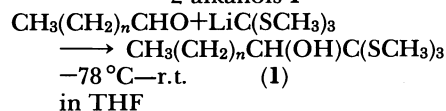
Myrmicacin was isolated from the secretion of South American leaf-cutting ants, *Atta sexdens*, and identified as (*R*)-(-)-3-hydroxydecanoic acid by Schildeknecht and Koob in 1971.¹⁾ It is understood that this substance prevents germination of collected seeds and intruding spores, as a herbicide, in the ant's nest. Recent studies revealed that it had a reversible inhibitory effect on pollen growth.^{2–6)} The activity of myrmic acids⁷⁾ on cleavage of fertilized sea urchin eggs,^{8,9)} HeLa cells,¹⁰⁾ human erythrocytes,¹¹⁾ and propagation of pathogenic bacteria in silk worm, *larvae*¹²⁾ has been reported. A close relationship between intensity of inhibitory activity and degree of lipophilicity of myrmicacin analogues has recently been found.^{13,14)} Strong inhibitory activity of 2-hydroxyalkanoic acids on pollen germination has also been observed.¹⁵⁾

In view of the above-stated facts, it seemed of significance for further study on biological activity of myrmicacin and related compounds to establish the synthetic method of 2-hydroxyalkanoic acids^{16a,17)} as well as 1,2-diols^{16b,17)} with a common starting material and to obtain their physical properties and spectral data. Thus the present study was undertaken.

Results and Discussion

To a solution of tris(methylthio)methanide ion, generated by interaction of tris(methylthio)methane with butyllithium at -78°C ,^{18–20)} was slowly added the tetrahydrofuran solution of the appropriate aldehydes (C_3 — C_{12}). By warming the mixture to room temperature, the corresponding tris(methylthio)methyl adducts (**1a—j**) were obtained in good yields, as shown in Table 1. Preliminary attempts to prepare the straight-chain 2-hydroxyalkanoic acids **5** were made by treating the adducts **1** with mercury(II) chloride or mercury(II) oxide in aqueous solution, according to the procedure described by Seebach.¹⁸⁾ In each case the main product was not the 2-hydroxyalkanoic acid but the *S*-methyl 2-hydroxyal-

Table 1. Synthesis of 1,1,1-Tris(methylthio)-2-alkanols **1**



Entry <i>n</i>	Products 1	
	Bp($^{\circ}\text{C}/\text{Torr}$)	Yield (%)
a: 1	154—155/14	75
b: 2	160—162/14	76
c: 3	171—173/14 ^{a)}	88
d: 4	180—181/14	89
e: 5	121—122/0.2	91
f: 6	127—128/0.2	89
g: 7	144—146/0.4	85
h: 8	142—145/0.2	87
i: 9	165—166/0.2	87
j: 10	176—177/0.2	95

a) Lit,¹⁸⁾ mp 60—63 $^{\circ}\text{C}$.

kanethioates **2**.^{19a)} When stirred in a suspension with mercury(II) chloride–mercury(II) oxide²⁰⁾ (2.5:1.0 mol) in water–acetone (1:5) at room temperature for 2 h, the adducts **1** were efficiently converted to the thioates **2** in the yields ranging in 75—95%, as summarized together with boiling and melting points of the analytical samples in Table 2.²¹⁾ When heated to reflux for 1 h, the thioates **2** were obtained also in good yield. Longer heating did not give much effect on further hydrolysis (desulfurization) to the acids. Boron trifluoride etherate–mercury(II) oxide¹⁹⁾ worked well and gave **2** in the yields comparable to those given for the aforementioned reactions in the presence of mercury(II) chloride–mercury(II) oxide. Similarly, when the adducts **1** were refluxed with mercury(II) chloride–mercury(II) oxide (2.5:1.0 mol) in methanol for 2 h, the ready formation of the methyl esters **3** took place. However, the esters with lower molecular weights were isolated in the lesser yields due to their water-soluble character (Table 3). Treatment of the *S*-methyl thioates **2** with excess

Table 2. Synthesis of *S*-Methyl Thioesters **2** from **1**
 $\text{CH}_3(\text{CH}_2)_n\text{CH}(\text{OH})\text{C}(\text{SCH}_3)_3$ (**1**)
 $\longrightarrow \text{CH}_3(\text{CH}_2)_n\text{CH}(\text{OH})\text{COSCH}_3$
 HgCl₂-HgO (2.5 : 1.0 mol) (**2**)
 in H₂O-acetone (1 : 5)
 at r.t. for 2 h

Entry <i>n</i>	Products 2		
	Bp(°C/Torr)	Mp (°C)	Yield (%)
a: 1	91/14		56
b: 2	104/14		63
c: 3	115/10		85
d: 4	119/7		87
e: 5	124/5		89
f: 6	95/0.2		83
g: 7	105/0.2	38	82
f: 8	118/0.2	34	81
g: 9	135/0.5	48	83
h: 10	144/0.6	41	83

Table 3. Synthesis of Methyl 2-Hydroxyalkanoates **3** from **1**
 $\text{CH}_3(\text{CH}_2)_n\text{CH}(\text{OH})\text{C}(\text{SCH}_3)_3$ (**1**)
 $\longrightarrow \text{CH}_3(\text{CH}_2)_n\text{CH}(\text{OH})\text{COOCH}_3$
 HgCl₂-HgO(2.5 : 1.0 mol) (**3**)
 in MeOH
 refluxing for 2 h

Entry <i>n</i>	Products 3		
	Bp(°C/Torr)	Mp (°C)	Yield (%)
c: 3	111/50		50
d: 4	127/50		57
e: 5	110/13		67
f: 6	108/5		75
g: 7	122/5		75
h: 8	105/1		78
i: 9	117/1	36—37	77
j: 10	128/1	39—42	80

Table 4. Synthesis of 1,2-Alkanediols **4** by LiAlH₄
 Reduction of *S*-Methyl Thioesters **2**
 $\text{CH}_3(\text{CH}_2)_n\text{CH}(\text{OH})\text{COSCH}_3$ (**2**)
 $\longrightarrow \text{CH}_3(\text{CH}_2)_n\text{CH}(\text{OH})\text{CH}_2\text{OH}$
 LiAlH₄ in ether
 refluxing for 2 h

Entry <i>n</i>	Products 4		
	Bp(°C/Torr)	Mp (°C)	Yield (%)
c: 3	78—79/0.6 ^{a)}		90
d: 4	77—81/0.1 ^{b)}		90
e: 5	81—85/0.1	30 ^{c)}	91
f: 6	92—93/0.1	35	90
g: 7	93—96/0.05	46—47 ^{d)}	95
h: 8		46—48	92
i: 9		55—56 ^{e)}	94
j: 10		61—62 ^{f)}	96

a) Lit.²⁴⁾ bp 96—98 °C/1.0;²⁵⁾ bp 75—80 °C/0.3;²⁶⁾ bp 119—120 °C/13.5. b) Lit.²⁶⁾ bp 122.5 °C/10. c) Lit.²⁴⁾ bp 103—105 °C/0.5, mp 29—30 °C;²⁶⁾ bp 131—132 °C/10;²⁷⁾ mp 30—30.5 °C. d) Lit.²⁴⁾ mp 48—49 °C;²⁷⁾ mp 48—49 °C. e) Lit.²⁴⁾ mp 56—58 °C;²⁶⁾ mp 60—60.5 °C;²⁷⁾ mp 60—61 °C. f) Lit.²⁸⁾ mp 61.2—62.4 °C.

Table 5. Saponification of *S*-Methyl Thioesters **2**
 $\text{CH}_3(\text{CH}_2)_n\text{CH}(\text{OH})\text{COSCH}_3$ (**2**)
 $\longrightarrow \text{CH}_3(\text{CH}_2)_n\text{CH}(\text{OH})\text{COOH}$
 5% NaOH-aq. MeOH
 refluxing for 1 h

Entry <i>n</i>	Products 5	
	Mp (°C)	Yield (%)
c: 3	60—61 ^{a)}	90
d: 4	65—66	87
e: 5	68—69 ^{b)}	85
f: 6	69—70 ^{c)}	87
g: 7	70—71 ^{d)}	88
h: 8	72—73 ^{e)}	86
i: 9	73—74	90
j: 10	76—77	91

a) Lit.²⁹⁾ mp 61—62 °C;²⁵⁾ mp 60—62.5 °C. b) Lit.³⁰⁾ mp 69—70 °C;³¹⁾ mp 69 °C. c) Lit.³¹⁾ mp 70 °C. d) Lit.³¹⁾ mp 70.5 °C. e) Lit.³¹⁾ mp 75 °C.

lithium aluminium hydride in boiling tetrahydrofuran gave the 1,2-diols **4** in essentially quantitative yields (Table 4). Saponification of the thioates **2** in the usual manner furnished the corresponding crystalline 2-hydroxyalkanoic acids **5** in good yields as well (Table 5).

Experimental

Melting points were determined on a Laboratory Devices MEL-TEMP, and are uncorrected. Boiling points are uncorrected. IR spectra were recorded using the neat samples, unless otherwise stated, on a Hitachi-Perkin Elmer Model 125 spectrophotometer. ¹H NMR spectra were run in CDCl₃ solutions with Me₄Si as an internal reference at ambient temperature and registered on a 90 MHz Hitachi R-22 spectrometer.

General Procedure for the Addition Reaction of Tris(methylthio)methylithium to Aldehydes. A stirred solution of tris(methylthio)methane (4.62 g, 0.03 mol)²⁰⁾ in dry THF (50 ml) under an atmosphere of nitrogen was cooled at -78 °C, *n*-BuLi (0.029 mol, 18.5 ml) of 10 w/v% hexane solution was dropwise added at such a rate that the temperature did not rise more than -15 °C (10 min or more). An additional stirring at -78 °C for 15 min gave a white suspension, probably, due to partly precipitated lithium salt of tris(methylthio)methane. A solution of the freshly distilled appropriate aldehyde (0.025 mol) in dry THF (20 ml) was gradually added in the course of 20 min and the mixture was kept stirring at -78 °C for further 1 h. The cooling bath was removed and the mixture was allowed to warm to room temperature (1 h). To this, saturated NH₄Cl solution (20 ml) was added, and the mixture was shaken. The aqueous layer was extracted with ether (20 ml × 2). The combined organic layers were washed with saturated brine (20 ml) and dried over anhydrous Na₂SO₄. Evaporation of the solvent left an oil, which was distilled in vacuo to give the pure alcohol.

1,1,1-Tris(methylthio)-2-butanol (1a). 4.0 g. IR 3460 cm⁻¹; ¹H NMR δ=1.03 (3H, br. t, *J*=7.0 Hz, CH₃), 1.75 (2H, m, CH₂), 2.18 (9H, s, 3 × SCH₃), 2.74 (1H, d, *J*=4.0 Hz, OH),²²⁾ 3.62 (1H, ddd, *J*=9.5, 4.0, 3.0 Hz, CHOH²³⁾→dd,

$J=9.5, 3.0$ Hz). Found: C, 39.61; H, 7.50; S, 45.29%. Calcd for $C_7H_{16}OS_3$: C, 39.59; H, 7.59; S, 45.29%.

1,1,1-Tris(methylthio)-2-pentanol (1b). 4.3 g. IR 3470 cm^{-1} ; 1H NMR $\delta=0.92$ (3H, br. t, $J=7.0$ Hz, CH_3), 1.1–1.9 (4H, m, $2 \times CH_2$) 2.19 (9H, s, $3 \times SCH_3$), 2.74 (1H, d, $J=4.0$ Hz, OH),²² 3.72 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.5, 3.0$ Hz). Found: C, 42.22; H, 7.90; S, 42.59%. Calcd for $C_8H_{18}OS_3$: C, 42.44; H, 8.01; S, 42.48%.

1,1,1-Tris(methylthio)-2-hexanol (1c). 5.3 g. IR 3430 cm^{-1} ; 1H NMR $\delta=0.87$ (3H, br. t, $J=7.0$ Hz, CH_3), 1.20 (4H, m, $2 \times CH_2$), 1.71 (2H, m, CH_2), 2.19 (9H, s, $3 \times SCH_3$), 2.72 (1H, d, $J=4.0$ Hz, OH),²² 3.71 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.5, 2.5$ Hz). Found: C, 44.69; H, 8.27; S, 39.83%. Calcd for $C_9H_{20}OS_3$: C, 44.69; H, 8.38; S, 40.00%.

1,1,1-Tris(methylthio)-2-heptanol (1d). 5.65 g. IR 3450 cm^{-1} ; 1H NMR $\delta=0.87$ (3H, br. t, $J=7.0$ Hz, CH_3), 1.32 (6H, m, $3 \times CH_2$), 1.71 (2H, m, CH_2), 2.18 (9H, s, $3 \times SCH_3$), 2.75 (1H, d, $J=4.0$ Hz, OH),²² 3.71 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.5, 2.5$ Hz). Found: C, 47.11; H, 8.65; S, 37.61%. Calcd for $C_{10}H_{22}OS_3$: C, 47.20; H, 8.71; S, 37.80%.

1,1,1-Tris(methylthio)-2-octanol (1e). 6.1 g. IR 3470 cm^{-1} ; 1H NMR $\delta=0.85$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.29 (8H, m, $4 \times CH_2$), 1.71 (2H, m, CH_2), 2.18 (9H, s, $3 \times SCH_3$), 2.74 (1H, d, $J=4.0$ Hz, OH),²² 3.70 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.5, 2.5$ Hz). Found: C, 49.14; H, 9.01; S, 35.66%. Calcd for $C_{11}H_{24}OS_3$: C, 49.21; H, 9.01; S, 35.82%.

1,1,1-Tris(methylthio)-2-nonanol (1f). 6.3 g. IR 3450 cm^{-1} ; 1H NMR $\delta=0.84$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.28 (10H, m, $5 \times CH_2$), 1.72 (2H, m, CH_2), 2.17 (9H, s, $3 \times SCH_3$), 2.73 (1H, d, $J=4.0$ Hz, OH),²² 3.71 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.5, 2.5$ Hz). Found: C, 51.02; H, 9.13; S, 34.16%. Calcd for $C_{12}H_{26}OS_3$: C, 51.02; H, 9.28; S, 34.04%.

1,1,1-Tris(methylthio)-2-decanol (1g). 6.5 g. IR 3460 cm^{-1} ; 1H NMR $\delta=0.85$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.28 (12H, m, $6 \times CH_2$), 1.72 (2H, m, CH_2), 2.18 (9H, s, $3 \times SCH_3$), 2.73 (1H, d, $J=4.0$ Hz, OH),²² 3.71 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.5, 2.5$ Hz). Found: C, 52.54; H, 9.46; S, 32.57%. Calcd for $C_{13}H_{28}OS_3$: C, 52.65; H, 9.52; S, 32.43%.

1,1,1-Tris(methylthio)-2-undecanol (1h). 6.8 g. IR 3460 cm^{-1} ; 1H NMR $\delta=0.84$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.25 (14H, m, $7 \times CH_2$), 1.72 (2H, m, CH_2), 2.18 (9H, s, $3 \times SCH_3$), 2.73 (1H, d, $J=4.0$ Hz, OH),²² 3.71 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.0, 2.0$ Hz). Found: C, 54.10; H, 9.76; S, 30.96%. Calcd for $C_{14}H_{30}OS_3$: C, 54.14; H, 9.74; S, 30.97%.

1,1,1-Tris(methylthio)-2-dodecanol (1i). 7.1 g. IR 3450 cm^{-1} ; 1H NMR $\delta=0.84$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.24 (16H, m, $8 \times CH_2$), 1.71 (2H, m, CH_2), 2.18 (9H, s, $3 \times SCH_3$), 2.73 (1H, d, $J=4.0$ Hz, OH),²² 3.71 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.5, 2.5$ Hz). Found: C, 55.76; H, 9.96; S, 29.81%. Calcd for $C_{15}H_{34}OS_3$: C, 55.50; H, 9.96; S, 29.63%.

1,1,1-Tris(methylthio)-2-tridecanol (1j). 8.05 g. IR 3470 cm^{-1} ; 1H NMR $\delta=0.84$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.24 (18H, m, $9 \times CH_2$), 1.71 (2H, m, CH_2), 2.18 (9H, s, $3 \times SCH_3$), 2.73 (1H, d, $J=4.0$ Hz, OH),²² 3.71 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.5, 2.5$ Hz). Found: C, 56.73; H, 10.15; S, 28.48%. Calcd for $C_{16}H_{38}OS_3$: C, 56.75; H, 10.15; S, 28.40%.

General Procedure for Preparation of S-Methyl 2-Hydroxyalkanethioates (2). A mixture of each orthothio-carboxylic acid trimethyl ester (1, 1 mmol), $HgCl_2$ (5 mmol), and HgO (red, 2 mmol) in a solution of H_2O -acetone (1 : 5, 30 ml) was refluxed with stirring for 2 h. Precipitates were filtered, and acetone was evaporated at room temperature. The residue was dissolved in CH_2Cl_2 , washed with

saturated NH_4Cl solution (2 ml), and dried over anhydrous Na_2SO_4 . Evaporation of the solvent gave the crude product, which was distilled in vacuo to afford the pure S-methyl 2-hydroxyalkanethioate **2**. Analytical samples of **2g–j** were prepared on crystallization from petroleum ether.

S-Methyl 2-Hydroxybutanethioate (2a). 150 mg. IR 3400, 1660 cm^{-1} ; 1H NMR $\delta=1.00$ (3H, br. t, $J=7.5$ Hz, CH_3), 1.82 (2H, m, CH_2), 2.23 (3H, s, SCH_3), 3.05 (1H, d, $J=6.0$ Hz, OH),²² 4.28 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.0, 4.5$ Hz). Found: C, 44.69; H, 7.57; S, 23.67%. Calcd for $C_5H_{10}O_2S$: C, 44.75; H, 7.51; S, 23.89%.

S-Methyl 2-Hydroxypentanethioate (2b). 186 mg. IR 3400, 1660 cm^{-1} ; 1H NMR $\delta=0.97$ (3H, br. t, $J=7.0$ Hz, CH_3), 1.53 (2H, m, CH_2), 1.71 (2H, m, CH_2), 2.35 (3H, s, SCH_3), 3.01 (1H, d, $J=6.0$ Hz, OH),²² 4.33 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=6.0, 4.0$ Hz). Found: C, 48.76; H, 8.22; S, 21.44%. Calcd for $C_6H_{12}O_2S$: C, 48.62; H, 8.16; S, 21.62%.

S-Methyl 2-Hydroxyhexanethioate (2c). 275 mg. IR 3400, 1660 cm^{-1} ; 1H NMR $\delta=0.92$ (3H, br. t, $J=7.0$ Hz, CH_3), 1.43 (4H, m, $2 \times CH_2$), 1.78 (2H, s, CH_2), 2.33 (3H, s, SCH_3), 3.09 (1H, d, $J=5.5$ Hz, OH),²² 4.33 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=7.0, 4.0$ Hz). Found: C, 51.79; H, 8.68; S, 19.83%. Calcd for $C_7H_{14}O_2S$: C, 51.83; H, 8.99; S, 19.76%.

S-Methyl 2-Hydroxyheptanethioate (2d). 306 mg. IR 3400, 1660 cm^{-1} ; 1H NMR $\delta=0.89$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.33 (6H, m, $3 \times CH_2$), 1.78 (2H, m, CH_2), 2.33 (3H, s, SCH_3), 3.01 (1H, d, $J=7.0$ Hz, OH),²² 4.33 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.0, 4.5$ Hz). Found: C, 54.49; H, 9.17; S, 18.16%. Calcd for $C_8H_{16}O_2S$: C, 54.51; H, 9.15; S, 18.19%.

S-Methyl 2-Hydroxyoctanethioate (2e). 338 mg. IR 3400, 1660 cm^{-1} ; 1H NMR $\delta=0.89$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.33 (8H, m, $4 \times CH_2$), 1.75 (2H, m, CH_2), 2.33 (3H, s, SCH_3), 3.02 (1H, d, $J=5.0$ Hz, OH),²² 4.33 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=8.0, 4.5$ Hz). Found: C, 56.85; H, 9.66; S, 16.73%. Calcd for $C_9H_{18}O_2S$: C, 56.80; H, 9.53; S, 16.85%.

S-Methyl 2-Hydroxynonanethioate (2f). 339 mg. IR 3400, 1660 cm^{-1} ; 1H NMR $\delta=0.87$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.30 (10H, m, $5 \times CH_2$), 1.75 (2H, m, CH_2), 2.32 (3H, s, SCH_3), 3.26 (1H, d, $J=5.0$ Hz, OH),²² 4.30 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=7.0, 4.5$ Hz). Found: C, 58.64; H, 9.88; S, 15.51%. Calcd for $C_{10}H_{20}O_2S$: C, 58.78; H, 9.87; S, 15.69%.

S-Methyl 2-Hydroxydecanethioate (2g). 357 mg. IR (Nujol) 3470, 1670 cm^{-1} ; 1H NMR $\delta=0.90$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.30 (12H, m, $6 \times CH_2$), 1.75 (2H, m, CH_2), 2.33 (3H, s, SCH_3), 2.95 (1H, d, $J=5.0$ Hz, OH),²² 4.33 (1H, m, CH_2OH^{23}) \rightarrow dd, $J=7.5, 4.0$ Hz). Found: C, 60.37; H, 10.09; S, 14.87%. Calcd for $C_{11}H_{22}O_2S$: C, 60.50; H, 10.16; S, 14.68%.

S-Methyl 2-Hydroxyundecanethioate (2h). 376 mg. IR (Nujol) 3470, 1665 cm^{-1} ; 1H NMR $\delta=0.89$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.26 (14H, m, $7 \times CH_2$), 1.75 (2H, m, CH_2), 2.34 (3H, s, SCH_3), 2.92 (1H, br. s, OH), 4.32 (1H, dd, $J=7.5, 4.0$ Hz, CH_2OH). Found: C, 61.93; H, 10.32; S, 13.77%. Calcd for $C_{12}H_{24}O_2S$: C, 62.02; H, 10.42; S, 13.80%.

S-Methyl 2-Hydroxydodecanethioate (2i). 408 mg. IR (Nujol) 3470, 1665 cm^{-1} ; 1H NMR $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.25 (16H, m, $8 \times CH_2$), 1.75 (2H, m, CH_2), 2.32 (3H, s, SCH_3), 2.65 (1H, br. s, OH), 4.32 (1H, d, $J=6.5, 4.0$ Hz, CH_2OH). Found: C, 63.28; H, 10.52; S, 12.99%. Calcd for $C_{13}H_{26}O_2S$: C, 63.37; H, 10.63; S, 13.01%.

S-Methyl 2-Hydroxytridecanethioate (2j). 430 mg. IR (Nujol) 3470, 1665 cm^{-1} ; 1H NMR $\delta=0.90$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.24 (18H, m, $9 \times CH_2$), 1.75 (2H, m, CH_2), 2.32 (3H, s, SCH_3), 2.65 (1H, br. s, OH), 4.32 (1H, dd, $J=6.5, 4.0$

Hz, CHOH). Found: C, 64.46; H, 10.69; S, 12.38%. Calcd for $\text{C}_{14}\text{H}_{28}\text{O}_2\text{S}$: C, 64.57; H, 10.84; S, 12.31%.

General Procedure for Preparation of Methyl Esters 3 from 1. A mixture of **1** (2 mmol), HgCl_2 (5 mmol), and HgO (red, 2 mmol) in a solution of 99% MeOH (20 ml) was refluxed for 1 h, and worked up in the same manner as noted for **2**. The crude oily product was distilled in vacuo.

Methyl 2-Hydroxyhexanoate (3c). 171 mg. IR 3450, 1730 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.89$ (3H, br. t, $J=7$ Hz, CH_3), 1.40 (4H, m, $2 \times \text{CH}_2$), 1.71 (2H, m, CH_2), 2.90 (1H, d, $J=6.0$ Hz, OH),²²⁾ 3.82 (3H, s, OCH_3), 4.26 (1H, m, CHOH^{23}) \rightarrow dd, $J=6.5, 4.5$ Hz). Found: C, 57.52; H, 9.53%. Calcd for $\text{C}_7\text{H}_{14}\text{O}_3$: C, 57.51; H, 9.65%.

Methyl 2-Hydroxyheptanoate (3d). 181 mg. IR 3460, 1730 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.89$ (3H, br. t, $J=7.0$ Hz, CH_3), 1.34 (6H, m, $3 \times \text{CH}_2$), 1.71 (2H, m, CH_2), 3.04 (1H, d, $J=6.0$ Hz, OH), 3.82 (3H, s, OCH_3),²²⁾ 4.21 (1H, m, CHOH^{23}) \rightarrow dd, $J=6.5, 6.0$ Hz). Found: C, 60.03; H, 10.16%. Calcd for $\text{C}_8\text{H}_{16}\text{O}_3$: C, 59.98; H, 10.07%.

Methyl 2-Hydroxyoctanoate (3e). 234 mg. IR 3450, 1732 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=7.5$ Hz, CH_3), 1.33 (8H, m, $4 \times \text{CH}_2$), 1.71 (2H, m, CH_2), 2.94 (1H, d, $J=5.5$ Hz, OH),²²⁾ 3.83 (3H, s, OCH_3), 4.25 (1H, m, CHOH^{23}) \rightarrow dd, $J=6.6, 6.0$ Hz). Found: C, 61.90; H, 10.32%. Calcd for $\text{C}_8\text{H}_{16}\text{O}_3$: C, 62.04; H, 10.41%.

Methyl 2-Hydroxynonanoate (3f). 282 mg. IR 3450, 1735 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.32 (10H, m, $5 \times \text{CH}_2$), 1.72 (2H, m, CH_2), 2.98 (1H, d, $J=5.5$ Hz, OH),²²⁾ 3.82 (3H, s, OCH_3), 4.25 (1H, m, CHOH^{23}) \rightarrow dd, $J=6.6, 6.0$ Hz). Found: C, 63.70; H, 10.75%. Calcd for $\text{C}_9\text{H}_{18}\text{O}_3$: C, 63.79; H, 10.71%.

Methyl 2-Hydroxydecanoate (3g). 302 mg. IR 3460, 1730 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.30 (12H, m, $6 \times \text{CH}_2$), 1.73 (2H, m, CH_2), 2.94 (1H, d, $J=5.5$ Hz, OH),²²⁾ 3.85 (3H, s, OCH_3), 4.25 (1H, m, CHOH^{23}) \rightarrow dd, $J=6.5, 5.5$ Hz). Found: C, 65.42; H, 10.87%. Calcd for $\text{C}_{10}\text{H}_{20}\text{O}_3$: C, 65.31; H, 10.96%.

Methyl 2-Hydroxyundecanoate (3h). 337 mg. IR 3460, 1735 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.27 (14H, m, $7 \times \text{CH}_2$), 1.73 (2H, m, CH_2), 2.97 (1H, br. s, OH), 3.85 (3H, s, OCH_3), 4.25 (1H, br. t, $J=6.5$ Hz, CHOH). Found: C, 66.69; H, 11.30%. Calcd for $\text{C}_{11}\text{H}_{22}\text{O}_3$: C, 66.63; H, 11.18%.

Methyl 2-Hydroxydodecanoate (3i). 355 mg. IR 3440, 1720 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.87$ (3H, br. t, $J=6.5$ Hz, CH_3), 1.27 (16H, m, $8 \times \text{CH}_2$), 1.73 (2H, m, CH_2), 2.84 (1H, br. d, $J=5.5$ Hz, OH),²²⁾ 3.85 (3H, s, OCH_3), 4.23 (1H, m, CHOH^{23}) \rightarrow dd, $J=6.0, 5.5$ Hz). Found: C, 67.88; H, 11.50%. Calcd for $\text{C}_{12}\text{H}_{24}\text{O}_3$: C, 67.78; H, 11.38%.

Methyl 2-Hydroxytridecanoate (3j). 391 mg. IR 3450, 1722 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.87$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.25 (18H, m, $9 \times \text{CH}_2$), 1.73 (2H, m, CH_2), 2.87 (1H, d, $J=6.5$ Hz, OH),²²⁾ 3.83 (3H, s, OCH_3), 4.23 (1H, m, CHOH^{23}) \rightarrow dd, $J=6.0, 5.5$ Hz). Found: C, 68.77; H, 11.46%. Calcd for $\text{C}_{14}\text{H}_{28}\text{O}_3$: C, 68.81; H, 11.55%.

Preparation of 1,2-Alkanediols (4) by LiAlH_4 Reduction of S-Methyl 2-Hydroxyalkanethioates (2). A stirred suspension of the appropriate thioate (**2**, 2 mmol) and LiAlH_4 (8 mmol, 300 mg) in dry ether (20 ml) was heated. After refluxing for 3 h, the mixture was cooled and water (about 2 ml) was added. The resulting white precipitates were filtered through a thin pad of powdered anhydrous MgSO_4 . The filtrate and ether washings were combined,

and evaporated to leave the crude diol, which was distilled under reduced pressure or crystallized from petroleum ether.

1,2-Hexanediol (4c). 213 mg. IR 3350 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.92$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.39 (6H, m, $3 \times \text{CH}_2$), 2.46 (2H, s, $2 \times \text{OH}$), 3.28–3.85 (3H, m, CHOHCH_2OH). Found: C, 60.87; H, 11.99%. Calcd for $\text{C}_6\text{H}_{14}\text{O}_2$: C, 60.98; H, 11.98%.

1,2-Heptanediol (4d). 238 mg. IR 3350 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.89$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.35 (8H, m, $4 \times \text{CH}_2$), 2.48 (2H, s, $2 \times \text{OH}$), 3.25–3.80 (3H, m, CHOHCH_2OH). Found: C, 63.41; H, 12.23%. Calcd for $\text{C}_7\text{H}_{16}\text{O}_2$: C, 63.59; H, 12.20%.

1,2-Octanediol (4e). 266 mg. IR (Nujol) 3350 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.30 (8H, m, $4 \times \text{CH}_2$), 1.38 (2H, m, CH_2), 2.01 (2H, s, $2 \times \text{OH}$), 3.28–3.85 (3H, m, CHOHCH_2OH). Found: C, 65.67; H, 12.43%. Calcd for $\text{C}_8\text{H}_{18}\text{O}_2$: C, 65.71; H, 12.41%.

1,2-Nonanediol (4f). 266 mg. IR (Nujol) 3300, 3230 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.29 (10H, m, $5 \times \text{CH}_2$), 1.39 (2H, m, CH_2), 2.00 (2H, s, $2 \times \text{OH}$), 3.30–3.85 (3H, m, CHOHCH_2OH). Found: C, 67.62; H, 12.53%. Calcd for $\text{C}_9\text{H}_{20}\text{O}_2$: C, 67.45; H, 12.58%.

1,2-Decanediol (4g). 288 mg. IR (Nujol) 3310, 3220 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.27 (12H, m, $6 \times \text{CH}_2$), 1.38 (2H, m, CH_2), 1.93 (2H, s, $2 \times \text{OH}$), 3.25–3.85 (3H, m, CHOHCH_2OH). Found: C, 67.62; H, 12.53%. Calcd for $\text{C}_{10}\text{H}_{22}\text{O}_2$: C, 68.91; H, 12.72%.

1,2-Undecanediol (4h). 331 mg. IR (Nujol) 3310, 3220 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.27 (14H, m, $7 \times \text{CH}_2$), 1.38 (2H, m, CH_2), 1.93 (2H, s, $2 \times \text{OH}$), 3.25–3.85 (3H, m, CHOHCH_2OH). Found: C, 70.22; H, 12.93%. Calcd for $\text{C}_{11}\text{H}_{24}\text{O}_2$: C, 70.16; H, 12.85%.

1,2-Dodecanediol (4i). 354 mg. IR (Nujol) 3310, 3220 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.26 (16H, m, $8 \times \text{CH}_2$), 1.38 (2H, m, CH_2), 2.14 (2H, br. s, $2 \times \text{OH}$), 3.25–3.85 (3H, m, CHOHCH_2OH). Found: C, 71.31; H, 13.11%. Calcd for $\text{C}_{12}\text{H}_{26}\text{O}_2$: C, 71.23; H, 12.95%.

1,2-Tridecanediol (4j). 388 mg. IR (Nujol) 3310, 3210 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.26 (18H, m, $9 \times \text{CH}_2$), 1.39 (2H, m, CH_2), 1.86 (2H, br. s, $2 \times \text{OH}$), 3.25–3.85 (3H, m, CHOHCH_2OH). Found: C, 72.89; H, 12.42%. Calcd for $\text{C}_{13}\text{H}_{28}\text{O}_2$: C, 72.84; H, 12.23%.

Preparation of 2-Hydroxyalkanoic Acids (5). A solution of the appropriate thioate (**2**, 2 mmol) in 90% MeOH (10 ml) containing 5% NaOH was refluxed for 1 h. MeOH was removed under reduced pressure. To the residue water (10 ml) was added and the resulting solution was extracted with ether (10 ml). Water layer was acidified with diluted HCl and extracted with CH_2Cl_2 (10 ml \times 2). The CH_2Cl_2 extracts were dried over anhydrous Na_2SO_4 , and evaporated to leave a solid. Recrystallization from petroleum ether gave the pure 2-hydroxyalkanoic acid.

2-Hydroxyhexanoic Acid (5c). 238 mg. IR (Nujol) 3600–2300, 3440, 3390, 1710 cm^{-1} ; (CHCl_3) 3600–2400, 1715 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.92$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.43 (4H, m, $2 \times \text{CH}_2$), 1.78 (2H, m, CH_2), 4.28 (1H, dd, $J=5.5, 4.4$ Hz, CHOH), 4.65 (2H, br. s, OH and COOH). Found: C, 54.46; H, 9.07%. Calcd for $\text{C}_6\text{H}_{12}\text{O}_3$: C, 54.53; H, 9.15%.

2-Hydroxyheptanoic Acid (5d). 254 mg. IR (Nujol) 3600–2300, 3440, 3390, 1710 cm^{-1} ; (CHCl_3) 3600–2400, 1715 cm^{-1} ; $^1\text{H NMR}$ $\delta=0.90$ (3H, br. t, $J=6.5$ Hz, CH_3), 1.34 (6H, m, $3 \times \text{CH}_2$), 1.72 (2H, m, CH_2), 4.28 (1H, dd, $J=5.5, 4.5$ Hz, CHOH), 5.82 (2H, br. s, OH and COOH). Found: C,

57.44; H, 9.51%. Calcd for $C_7H_{14}O_3$: C, 57.51; H, 9.65%.

2-Hydroxyoctanoic Acid (5e). 272 mg. IR (Nujol) 3600—2300, 3430, 3380, 1705 cm^{-1} ; ($CHCl_3$) 3600—2400, 1715 cm^{-1} ; 1H NMR $\delta=0.89$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.33 (8H, m, $4 \times CH_2$), 1.78 (2H, m, CH_2), 4.28 (1H, dd, $J=5.5, 5.0$ Hz, $CH(OH)$), 5.58 (2H, br. s, OH and $COOH$). Found: C, 59.91; H, 10.02%. Calcd for $C_8H_{16}O_3$: C, 59.98; H, 10.07%.

2-Hydroxynonanoic Acid (5f). 303 mg. IR (Nujol) 3600—2300, 3430, 3380, 1705 cm^{-1} ; ($CHCl_3$) 3600—2400, 1715 cm^{-1} ; 1H NMR $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.30 (10H, m, $5 \times CH_2$), 1.78 (2H, m, CH_2), 4.28 (1H, dd, $J=6.5, 5.0$ Hz, $CH(OH)$), 5.76 (2H, br. s, OH and $COOH$). Found: C, 61.91; H, 10.62%. Calcd for $C_9H_{18}O_3$: C, 62.04; H, 10.41%.

2-Hydroxydecanoic Acid (5g). 331 mg. IR (Nujol) 3600—2300, 3450, 1740 cm^{-1} ; ($CHCl_3$) 3600—2400, 3510, 1715 cm^{-1} ; 1H NMR $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.28 (12H, m, $6 \times CH_2$), 1.78 (2H, m, CH_2), 4.28 (1H, dd, $J=6.5, 5.0$ Hz, $CH(OH)$), 6.19 (2H, br. s, OH and $COOH$). Found: C, 63.72; H, 10.76%. Calcd for $C_{10}H_{20}O_3$: C, 63.79; H, 10.71%.

2-Hydroxyundecanoic Acid (5h). 350 mg. IR (Nujol) 3600—2300, 3550, 1690 cm^{-1} ; ($CHCl_3$) 3600—2400, 3510, 1715 cm^{-1} ; 1H NMR $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.27 (14H, m, $7 \times CH_2$), 1.78 (2H, m, CH_2), 4.27 (1H, dd, $J=6.5, 4.5$ Hz, $CH(OH)$), 5.52 (2H, br. s, OH and $COOH$). Found: C, 65.20; H, 10.99%. Calcd for $C_{11}H_{22}O_3$: C, 65.31; H, 10.96%.

2-Hydroxydodecanoic Acid (5i). 389 mg. IR (Nujol) 3600—2400, 3540, 1745, 1690 cm^{-1} ; ($CHCl_3$) 3600—2400, 3510, 1715 cm^{-1} ; 1H NMR $\delta=0.88$ (3H, br. t, $J=6.5$ Hz, CH_3), 1.26 (16H, m, $8 \times CH_2$), 1.78 (2H, m, CH_2), 4.27 (1H, dd, $J=6.5, 5.0$ Hz, $CH(OH)$), 4.57 (2H, br. s, OH and $COOH$). Found: C, 66.44; H, 11.23%. Calcd for $C_{12}H_{24}O_3$: C, 66.63; H, 11.18%.

2-Hydroxytridecanoic Acid (5j). 491 mg. IR (Nujol) 3600—2400, 3540, 1745, 1690; ($CHCl_3$) 3600—2400, 3510, 1715 cm^{-1} ; 1H NMR $\delta=0.88$ (3H, br. t, $J=6.0$ Hz, CH_3), 1.26 (18H, m, $9 \times CH_2$), 1.78 (2H, m, CH_2), 4.27 (1H, dd, $J=6.5, 5.5$ Hz, $CH(OH)$), 4.47 (2H, br. s, OH and $COOH$). Found: C, 67.72; H, 11.31%. Calcd for $C_{13}H_{26}O_3$: C, 67.78; H, 11.38%.

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