Reinvestigation of Base-Catalyzed Condensation of Ethyl α,α-Dichloroacetoacetate with Aldehydes. A New Synthesis of (±)-Disparlure

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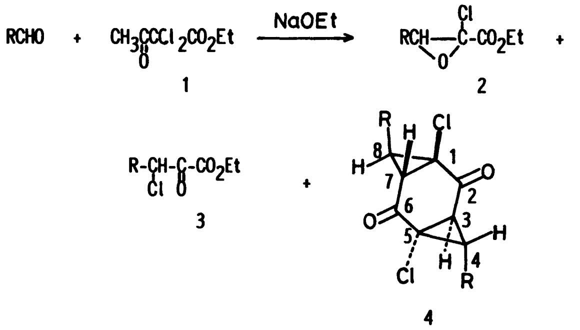
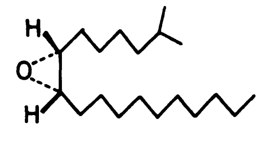
The titled reaction gave ethyl 2-chloro-2,3-epoxyalkanoates (**2**) and ethyl 3-chloro-2-oxoalkanoates in improved yields. The structure of the by-product was revised as 1,5-dichloro-4,8-dialkyltricyclo[5.1.0.0^{3,5}]octane-2,6-dione by means of the ^{13}C–^{1}H two-dimensional NMR spectrum and an X-ray crystallographic analysis. Compound **2** was applied to the synthesis of (±)-disparlure, the pheromone of the gypsy moth, in 49% overall yield via 6 steps.

As our continuing study on α-halo carbonyl compounds,[1] we have reported the reaction of ethyl α,α-dichloroacetoacetate (**1**) with aldehydes in the presence of sodium ethoxide.[2] This novel reaction involving a retro acetoacetate reaction[3] gave ethyl 2-chloro-2,3-epoxyalkanoate (**2**) or ethyl 3-chloro-2-oxoalkanoate (**3**) in low or moderate yields together with a small amount of crystalline by-products, one of which was identified as 2,5-bis(1-chloroalkylidene)-1,4-cyclohexanedione (**4′**).[2]



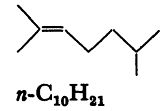
Recently, we reinvestigated this reaction in order to improve the yields of **2** and **3**; we also reexamined the structure of the by-product by means of the ^{13}C-^{1}H two-dimensional NMR spectrum and an X-ray crystallographic analysis. In the present paper we describe the results, which involve a revision of the previously assigned structure **4′** to 1,5-dichloro-4,8-dialkyltricyclo[5.1.0.0^{3,5}]octane-2,6-dione (**4**) as well as a highly stereoselective synthesis of the racemate of (+)-disparlure[(7*R*,8*S*)-7,8-epoxy-2-methyloctadecane] (**5**),[4] the pheromone of the gypsy moth.



(+)-Disparlure **5**

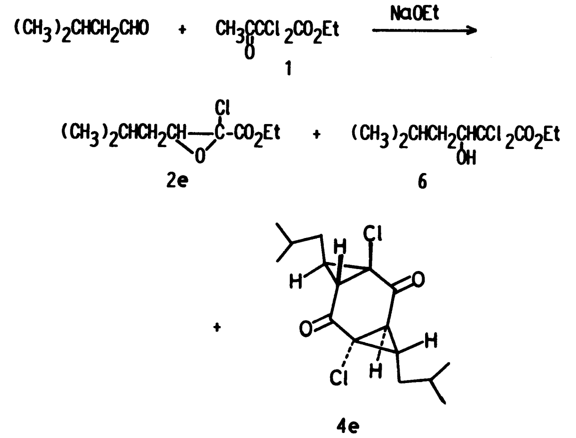
When we carried out the present reaction under an absolutely dry conditions,[5] the yields of the products **2** and **3** ($R=C_6H_5$) were dramatically improved, as shown in Table 1, although the crystalline by-product

Table 1. Products from the Reaction of **1** with Aldehydes

No.	R	Yield$^{a,b)}$/% of **2** and/or **3**	Bp (θ_b/°C)/Torr$^{c)}$ of **2** and/or **3**	Yield$^{a)}$/% of **4**
a	CH_3	**2a** (30.4)		
b	C_2H_5	**2b** 73.9 (68.6)	115—130/2.5	**4b** 0 (6.1)
c	n-C_3H_7	**2c** 96.0	135/4	
d	$(CH_3)_2CH$	**2d** 83.2 (24.7)	130/2.5	**4d** 0 (3.7)
e	$(CH_3)_2CHCH_2$	**2e** 66.7	140/2	
f	n-C_6H_{13}	**2f**/**3f** (2/1) 54.7 (14.4)	200/3	**4f** 0 (7.9)
		2f 90$^{d)}$		
g	C_6H_5	**3g** 77.1 (16.4)	190/3	**4g** 0 (5.9)
		2g 100		
h	n-C_8H_{17}	**2h** 69.7$^{d)}$		
i		**2i** 80.7$^{d)}$		
j	n-$C_{10}H_{21}$	**2j** 73.6$^{d)}$	200/0.3	**4j** 5.5

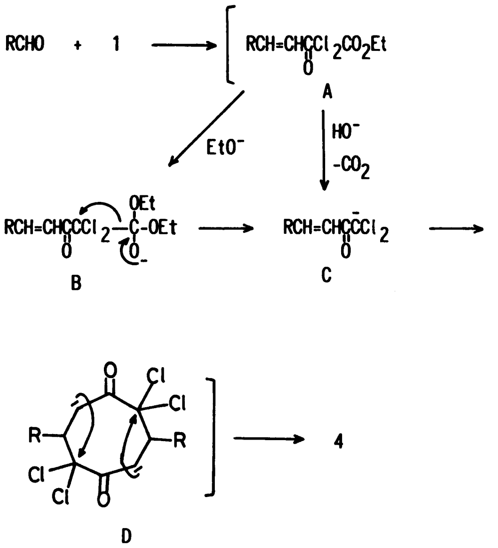
a) Previously reported values$^{2)}$ are given in parenthesis. b) Isolated yields by distillation unless otherwise indicated. c) Bath temperature of bulb-to-bulb tube oven. d) Isolated yield by column chromatography.

4 produced before[2)] was not isolated. All of the reactions gave the epoxide **2** in good yields. The epoxides **2a**—**e** (R=CH_3, C_2H_5, *n*-C_3H_7, $(CH_3)_2CH$, $(CH_3)_2CHCH_2$) bearing small alkyl groups were thermally stable, while the epoxides (**2f** and **2g**) (R=*n*-C_6H_{13}, C_6H_5) bearing larger groups were isomerized to keto esters (**3f** and **3g**) by distillation via halo-epoxy rearrangement.[1a,b)] On the other hand, the reaction of **1** with 3-methylbutanal in the presence of commercial, old sodium ethoxide gave **4e** (R=$(CH_3)_2CHCH_2$) in 4.8% yield besides **2e** (R=$(CH_3)_2CHCH_2$) (18%) and ethyl 2,2-dichloro-3-hydroxy-5-methylhexanoate (**6**) (30%). Similarly, the reaction of **1** with undecanal under the same conditions gave **2j** (R=*n*-$C_{10}H_{21}$) in 73.6% yield and **4j** (R=*n*-$C_{10}H_{21}$) in 5.65% yield. Measurement of the ^{13}C NMR spectra of **4** coupled with that of the heteronuclear ^{13}C-^1H chemical shift correlated spectrum (HETCOR), led us to assign all the carbon signals (Table 2). The result indicated that the structure of **4′** was incorrect owing to the absence of signals due to olefinic carbons.



The structure of **4** was absolutely verified by a representative X-ray crystallographic analysis of **4b** (R=C_2H_5) to be 1,5-dichloro-4,8-diethyltricyclo[5.1.0.0^{3,5}]octane-2,6-dione. ORTEP drawing in Fig. 1 illustrates the geometrical aspect of the molecule and explains the chemical structure reasonably. The molecule is located about a crystallographic center and the asymmetric unit contains half of the molecule.

Although the accurate mechanism is not clear, the formation of **4** can be explained by assuming intermediates **A**, **B**, **C**, and **D**. Aldol condensation product **A** between aldehydes and **1** would give an anion **C** via the intermediate **B**. Two molecules of the anion **C** would undergo a Michael addition each other to afford a cyclized product **D**. The subsequent double dehydrochlorinations of **D** would give the final product **4**.



Furthermore, compound **2j** was utilized for the synthesis of the racemate of (+)-disparlure **5**. Since (±)-**5** and (+)-**5** are effective as an attractant against the harmful forest pest like gypsy moth, their syntheses

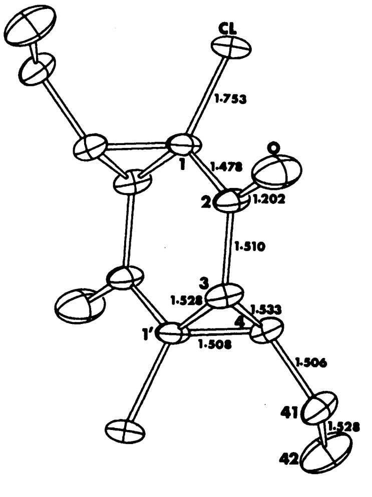
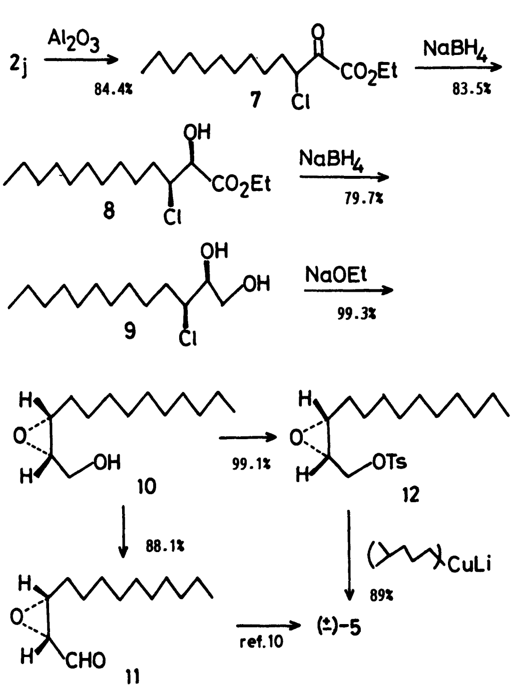


Fig. 1. ORTEP drawing of **4b**.

Table 2. ^{13}C NMR Data of **4**

No.	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	Others
4b[a)]	50.3	192.5	39.8	33.9	50.3	192.5	39.8	33.9	22.4 12.6
4d[a)]	50.4	192.2	39.6	39.3	50.4	192.2	39.6	39.3	30.0 21.5 21.2
4e	50.3	192.7	39.8	32.8	50.3	192.7	39.8	32.8	31.5 28.7 28.1 22.5 14.0
4j	50.3	192.5	39.8	32.7	50.3	192.5	39.8	32.7	31.8 29.4 29.3 29.0 28.7 28.1 22.6 14.0

a) Prepared in the previous paper. See Ref. 2.



Scheme 1.

have been reported repeatedly to date.[6,7] Our synthetic sequence is shown in Scheme 1. A thermal treatment of **2j** with alumina in xylene induced a chlorocarbonyl rearrangement[1c] to give ethyl 3-chloro-2-oxotridecanoate (**7**) in 84.4% yield. Reduction of **7** with sodium borohydride in ethanol at 0°C afforded ethyl 3-chloro-2-hydroxytridecanoate (**8**) in 83.5% yield with high stereoselectivity (threo/erythro = 93/7). Purification of a stereoisomeric mixture with preparative HPLC afforded pure *threo*-**8**, which was reduced again with sodium borohydride at room temperature to give *threo*-3-chloro-1,2-tridecanediol (**9**) in 79.7% yield. Dehydrochlorination of **9** with sodium ethoxide in ethanol gave *cis*-2,3-epoxy-1-tridecanol (**10**)[8] in a quantitative yield. Reaction of **10** with tosyl chloride affored tosylate **12** in 99.1% yield. Treatment of **12** with lithium bis(4-methylpentyl)cuprate(I) gave (±)-disparlure **5** in 89% yield. A total synthesis of (±)-**5** was established in 49% overall yield via 6 steps starting from **2j**. Furthermore, the oxidation of **10** with a Collins reagent afforded *cis*-2,3-epoxytridecanal (**11**) in 88.1% yield; this could be converted to (±)-**5** via a Wittig reaction and hydrogenation.[8]

Experimental

Melting and boiling points are uncorrected. Elemental analyses were carried out by Mr. Eiichiro Amano in our laboratory. Infrared (IR) spectra were obtained with a JASCO Model A-102 infrared spectrophotometer. ^{1}H NMR (100 MHz) and ^{13}C NMR spectra (25 MHz) were obtained with a JEOL JNM-FX100 apparatus, using $\mathrm{CDCl_3}$ as a solvent. Two-dimensional NMR spectra were acquired on a Varian VXR 300 spectrometer operating at 300 and 75 MHz for ^{1}H and ^{13}C observation, respectively. Spectra were obtained for solutions in 5-mm NMR sample tubes in the ^{1}H-^{13}C switchable probe. Heteronuclear correlation spectra (HETCOR)[9] were run with the standard Varian 6.1-version software and obtained with sweep widths dictated by the appearance of the ^{13}C and ^{1}H spectra by using a 1024×512 data matrix and 128 increments in the first dimension.

Unless otherwise indicated, solvent (ether) was dried by distillation in the presence of sodium-benzophenone complex. Aldehydes were distilled prior to use.

Some representative examples of reactions of **1** with aldehydes are shown below.

Ethyl 2-Chloro-4-methyl-2,3-epoxypentanoate (2d) was prepared according to the procedure previously reported.[2] Sodium ethoxide was freshly prepared by dissolving sodium (250 mg, 11 mg-atom) in absolute ethanol (8 ml). After concentration of the solvent in vacuo, dry ether (50 ml) was added. To a stirred mixture was added dropwise ethyl α,α-dichloroacetoacetate (2.00 g, 10.1 mmol) at 0°C and then isobutyraldehyde (0.70 g, 0.9 ml, 9.5 mmol) was added dropwise. The mixture was stirred for 30 min at 0°C; it was then heated at the reflux temperature for 4 h, and poured into ice water. After the mixture was neutralized with 10% HCl, the organic materials were extracted with ethyl acetate. The combined extracts were washed with water and dried over $\mathrm{MgSO_4}$. Removal of the solvent gave 2.01 g of an oil, which was distilled with bulb-to-bulb tube oven, giving 1.52 g (83.2%) of **2d**: Bp 130°C/2.5 Torr (1 Torr = 133.322 Pa). The IR and ^{1}H NMR data were consistent with those of an authentic sample.[2]

Reaction of 1 with 3-Methylbutanal. 1,5-Dichloro-4,8-diisobutyltricyclo[5.1.0.0^{3,5}]octane-2,6-dione (4e). Commercial sodium ethoxide (1.6 g, 24 mmol) in ether (50 ml) was added in several portions to a solution of **1** (4.0 g, 20.1 mmol) in dry ether (50 ml) with stirring at 0°C. The mixture was stirred for 10 min and then 3-methylbutanal (1.6 g, 2.0 ml, 19 mmol) was added dropwise. After being stirred for 30 min at 0°C and for 30 min at 25°C, the mixture was heated under reflux for 4 h and then poured into ice water. The mixture was neutralized with 10% HCl, and the organic materials were extracted with ethyl acetate. The combined extracts were washed with water, dried over $\mathrm{MgSO_4}$, and concentrated. The residual oil containing crystals was filtered and washed with hexane to give 287 mg (4.8%) of **4e**: Mp 175—176°C (from hexane-ether); IR (KBr) 3050, 2960, 1699, 1285, 1100, and 875 cm^{-1}; ^{1}H NMR ($\mathrm{CDCl_3}$) $\delta=0.98$ (d, 12H, J = 6 Hz, $2(\mathrm{C\underline{H}_3})_2\mathrm{CH}$), 1.4—2.1 (m, 8H, $2(\mathrm{CH_3})_2\mathrm{\underline{C}\underline{H}C\underline{H}_2C\underline{H}}<$), and 2.23 (d, 2H, J=5.5 Hz, 2COCH). Found: C, 60.62; H, 7.14%. Calcd for $\mathrm{C_{16}H_{22}Cl_2O_2}$: C, 60.57; H, 6.99%.

Concentration of the filtrate gave an oil which was chromatographed on $\mathrm{SiO_2}$ (hexane-acetone, 20 : 1—2 : 1) to afford 2.07 g of a mixture of **2e**[1c] (18%) and **6** (30%): 1 : 2 ratio by ^{1}H NMR analysis; TLC (hexane-acetone, 5 : 1), R_f = 0.34.

Compound **6** was prepared independently by the reaction of ethyl dichloroacetate with 3-methylbutanal in the presence of commercial sodium ethoxide: 35% yield; bp 100—108°C/2 Torr; IR (neat) 3500, 1745 cm^{-1}; ^{1}H NMR ($\mathrm{CCl_4}$) δ=0.95 (d, 3H, J=6 Hz, $(\mathrm{C\underline{H}_3})_2\mathrm{CH}$), 0.98 (d, 3H, J=6 Hz, $(\mathrm{C\underline{H}_3})_2\mathrm{CH}$), 1.35 (t, 3H, J=6.5 Hz, $\mathrm{CO_2CH_2C\underline{H}_3}$), 1.3—2.2

(m, 3H, $(CH_3)_2C\underline{H}C\underline{H}_2$), 3.0 (br. s, 1H, OH), 4.12 (t, 1H, J =5 Hz, $C\underline{H}OH$), and 4.26 (q, 2H, J=6.5 Hz, $CO_2C\underline{H}_2CH_3$). Found: C, 44.16; H, 6.69%. Calcd for $C_9H_{16}Cl_2O_3$: C, 44.45; H, 6.63%.

Ethyl 2-Chloro-2,3-epoxytridecanoate (2j) and 1,5-Dichloro-4,8-didecyltricyclo[5.1.0.0^{3,5}]octane-2,6-dione (4j). A mixture of undecanal (3.40 g, 4.12 ml, 20 mmol) and ethyl α,α-dichloroacetoacetate (4 g, 20.1 mmol) in the presence of commercial sodium ethoxide (1.6 g, 24 mmol) was heated under reflux for 17 h, and then worked up. The crude products containing crystals were filtered and washed with hexane to give 536 mg (5.50%) of **4j**: Mp 93.5—94.0°C, IR (KBr) 1700, 1458, 1298, 1280, 1140, and 875 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=0.90 (br. t, 6H, J=5Hz, CH_3), 1.28 (m, 36H, $2(CH_2)_8$), and 1.50—2.30 (m, 4H, 4 >CH-). Found: C, 69.46; H, 9.39%. Calcd for $C_{28}H_{46}Cl_2O_2$: C, 69.26; H, 9.55%.

Concentration of the filtrate gave an oil which was chromatographed on SiO_2 (hexane-acetone, 20 : 1) to afford 4.30 g (73.6% yield) of **2j**: TLC (hexane-acetone, 5 : 1), R_f=0.32; IR (neat) 1750, 1465, 1255, 1020, and 715 cm^{-1}; ^{1}H NMR (CCl_4) δ= 0.90 (br. t, 3H, J=5 Hz, CH_3), 1.27 (m, 18H, $(CH_2)_9$), 1.30 (t, 3H, $CO_2CH_2C\underline{H}_3$), 3.30 (m, 1H, >CH-O-CCl), and 4.25 (m, 2H, $CO_2C\underline{H}_2CH_3$). Found: C, 61.90; H, 9.26%. Calcd for $C_{15}H_{27}ClO_3$: C, 61.95; H, 9.35%.

Compounds **2h** and **2i** were also obtained according to the same procedure as described above.

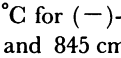
Ethyl 3-Chloro-2-oxoundecanoate (2h): IR (neat) 2950, 1750, 1470, 1255, 1030, and 870 cm^{-1}; ^{1}H NMR (CCl_4) δ= 0.90 (br, t, 3H, J=5 Hz, CH_3), 1.30 (q, 3H, J=7 Hz, $CO_2CH_2C\underline{H}_3$), 1.20—2.40 (m, 14H, $(CH_2)_7$), 3.25 (t, 1H, J =3 Hz, >CH-O-), and 4.20 (m, 2H, $CO_2C\underline{H}_2CH_3$). Found: C, 59.61; H, 8.75%. Calcd for $C_{13}H_{23}ClO_3$: C, 59.42; H, 8.82%.

Ethyl 2-Chloro-5,9-dimethyl-2,3-epoxy-8-decenoate (2i): IR (neat) 2950, 1750, 1450, 1380, 1270, and 1030 cm^{-1}; ^{1}H NMR (CCl_4) δ=0.85—2.40 (m, 10H, $(CH_2)_2$-$CHCH_3CH_2$), 1.33 (t, 3H, J=7 Hz, $CO_2CH_2C\underline{H}_3$), 1.56 (s, 3H, $(C\underline{H}_3)_2C$=CH), 1.65 (s, 3H, $(C\underline{H}_3)_2C$=CH), 3.35 (t, 1H, J=7 Hz, >CHO-), 4.25 (q, 2H, J=7 Hz, $CO_2C\underline{H}_2CH_3$), and 5.05 (m, 1H, $(CH_3)_2C$=$C\underline{H}$). Found: C, 61.33; H, 8.26%. Calcd for $C_{14}H_{23}ClO_3$: C, 61.20; H, 8.44%.

Ethyl 3-Chloro-2-oxotridecanoate (7) was prepared by the procedure reported previously.[1c] A mixture of **2j** (9.71 g, 33.4 mmol), alumina (10 g), and xylene (25 ml) was heated under reflux with stirring for 2 h. After filtration, the solvent was evaporated to give an oil which was chromatographed on SiO_2 (hexane-acetone, 20 : 1), giving 8.20 g (84.4%) of **7**: IR (neat) 2950, 1735, 1470, 1300, 1070, and 790 cm^{-1}; ^{1}H NMR (CCl_4) δ= 0.90 (br. t, 3H, J=5.5 Hz, CH_3), 1.27 (m, 18H, $(CH_2)_9$), 1.38 (t, 3H, J=7 Hz, $CO_2CH_2C\underline{H}_3$), 4.21 (q, 2H, J=7 Hz, $CO_2C\underline{H}_2CH_3$), and 4.82 (t, 1H, J=6 Hz, CHCl). Found: C, 61.94; H, 9.12%. Calcd for $C_{15}H_{27}ClO_3$: C, 61.95; H, 9.36%.

Ethyl *threo*-3-Chloro-2-hydroxytridecanoate (8). To a stirred mixture of $NaBH_4$ (52 mg, 1.37 mmol) and dry ethanol (3 ml) was added a solution of **7** (1.19 g, 4.10 mmol) in dry ethanol (2 ml) at 0°C. The mixture was stirred for 10 min at 0°C, then poured into ice water and neutralized with dilute HCl. The organic materials were extracted with dichloromethane, washed with water, and dried over $MgSO_4$. Concentration of the solvent gave a crude product (1.23 g) which was chromatographed on SiO_2 (hexane-acetone, 10 : 1) to give 1.00 g (84%) of **8**: threo/erythro (93 : 7) by HPLC analysis [column, SA-I (6 mmϕ × 250 mm); eluent, hexane-ethyl acetate (10 : 1), 1.25 ml min^{-1}]. Preparative HPLC gave 603 mg of *threo*-**8**: R_t= 13.5 min; IR (neat) 3430, 1745, 1465, 1270, and 1135 cm^{-1}; ^{1}H NMR (CCl_4) δ=0.86 (br. t, 3H, J= 5 Hz, CH_3), 1.28 (br. s, 18H, $(CH_2)_9$), 1.30 (t, 3H, J= 7 Hz, $CO_2CH_2C\underline{H}_3$), 4.16 (m, 2H, $C\underline{H}Cl$-$C\underline{H}OH$-), and 4.25 (q, 2H, J=7 Hz, $CO_2C\underline{H}_2CH_3$). Found: C, 61.72; H, 9.92%. Calcd for $C_{15}H_{29}ClO_3$: C, 61.52; H, 9.98%. The component of R_t=21.6 min gave 64.4 mg of *erythro*-**8**: IR (neat) 3500, 1745, 1470, 1220, and 1130 cm^{-1}; ^{1}H NMR (CCl_4) δ=0.86 (br. t, 3H, J=5 Hz, CH_3), 1.28 (br. s, 18H, $(CH_2)_9$), 1.30 (t, 3H, J= 7 Hz, $CO_2CH_2C\underline{H}_3$), 4.16 (m, 2H, $C\underline{H}ClC\underline{H}OH$), and 4.25 (q, 2H, J=7 Hz, $CO_2C\underline{H}_2CH_3$). Found: C, 61.70; 9.85%. Calcd for $C_{15}H_{29}ClO_3$: C, 61.52; H, 9.98%.

***threo*-3-Chloro-1,2-tridecanediol (9).** To a stirred mixture of $NaBH_4$ (266 mg, 7.0 mmol) and absolute ethanol (6 ml) was added a solution of **8** (1.64 g, 5.61 mmol) in absolute ethanol (4 ml) at 0°C. The mixture was stirred for 5 h at room temperature, then poured into ice water and neutralized with dilute HCl. The organic materials were extracted with dichloromethane. The combined extracts were washed with water, dried over $MgSO_4$, and the solvent was evaporated. The residual oil (1.40 g) was chromatographed on SiO_2 (hexane-acetone, 3 : 1) to give 1.12 g (79.7%) of **9**: TLC (hexane-acetone, 3 : 1), R_f = 0.37; mp 60 — 60.5°C (from pentane); IR (KBr) 3260, 2920, 1461, 1040, 1009, 882, and 690 cm^{-1}; ^{1}H NMR (CCl_4) δ= 0.90 (br. t, 3H, J= 5.5 Hz, CH_3), 1.28 (br. s, 16H, $(CH_2)_8$), 1.5—2.7 (m, 4H, 2OH, $C\underline{H}_2CHCl$), and 3.5—4.2 (m, 4H, $C\underline{H}ClC\underline{H}OHC\underline{H}_2OH$). Found: C, 62.36; H, 10.92%. Calcd for $C_{13}H_{27}ClO_2$: C, 62.26; H, 10.85%.

***cis*-2,3-Epoxy-1-tridecanol (10).**[8] Sodium (104 mg, 4.5 g-atom) was dissolved in 6 ml of absolute ethanol; a solution of **7** (1.01 g, 4.03 mmol) in absolute ethanol (4 ml) was added at 0°C. The mixture was stirred for 7 h at room temperature and then poured into ice water. After neutralization with dilute HCl, the organic materials were extracted with dichloromethane. The combined extracts were washed with water and dried over $MgSO_4$. The solvent was removed and the residual oil (1.12 g) was chromatographed on SiO_2 (hexane-acetone, 5 : 1), giving 856 mg (99.3%) of **10**: TLC (hexane-acetone, 3 : 1), R_f=0.30. Recrystallization from pentane gave 838 mg (97.2%) of **10**: mp 59.5 — 60.0°C (lit,[8b] 62.5 — 63.0°C for (−)-**10**; IR (KBr) 3500, 3400, 1461, 1103, 1027, 880, and 845 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ= 0.89 (br. t, 3H, J= 5 Hz, CH_3), 1.05—1.95 (m, 19H, $(CH_2)_9$ and OH), 3.1 (m, 2H,  $\overset{O}{-C\underline{H}-C\underline{H}-}$), and 3.73 (m, 2H, $C\underline{H}_2OH$).

***cis*-2,3-Epoxytridecanal (11).**[8b] In a 50 ml two-necked flask was charged chromium trioxide (0.625 g, 6.25 mmol) and dried in vacuo under nitrogen. A solution of dry pyridine (1.97 g, 2 ml, 12.5 mmol) in dry CH_2Cl_2 (11 ml) was slowly added and the mixture was stirred for 30 min. After a solution of **10** (0.149 mg, 0.69 mmol) in dry CH_2Cl_2 (4 ml) was added dropwise, the mixture was stirred for 2.4 h and the organic materials were extracted with ether. The combined extracts were washed with 5% NaOH (10 ml), dilute HCl (10 ml), neutralized with aqueous $NaHCO_3$, washed with brine, and dried over $MgSO_4$. Evaporation of the solvent gave 0.151 g of an oil which was chromatographed on SiO_2 (hexane-acetone, 15 : 1) to give 0.128 g (88.1 %) of **11**:[8b] IR (neat) 2950, 1730, 1470, and 840 cm^{-1}; ^{1}H NMR (CCl_4) $\delta = 0.86$ (br. t, 3H, $J = 5$ Hz, CH_3), 1.26 (m, 18H, $(CH_2)_9$), 3.15 (d, 2H, $J = 3.2$ Hz, $>\mathrm{C\underline{H}}$-O-$\mathrm{C\underline{H}}<$), and 9.30 (d, 1H, $J = 6.0$ Hz, CH=O).

2,3-Epoxytridecyl *p*-Toluenesulfonate (12). To 251 mg (1.32 mmol) of *p*-toluenesulfonyl chloride was added a solution of **10** (109 mg, 0.51 mmol) in pyridine (2 ml) at 0°C under an atmosphere of nitrogen. The mixture was stirred for 12 h and then poured into ice-water. The organic materials were extracted with ether. The combined extracts were washed with saturated $CuSO_4$, brine, and water successively, and dried over $MgSO_4$. Removal of the solvent gave 467 mg of an oil which was purified by preparative TLC (hexane-acetone, 3 : 1) to give 187 mg (99.1%) of **12**: TLC (hexane-acetone, 3 : 1), $R_f = 0.33$—0.46: IR (neat) 2940, 1595, 1365, 1180, 1095, 970, 815, and 660 cm^{-1}; ^{1}H NMR (CCl_4) $\delta = 0.90$ (br. t, 3H, $J = 5$ Hz, CH_3), 1.30 (m, 18H, $(CH_2)_9$), 2.45 (s, 3H, $\mathrm{C\underline{H}_3C_6H_4}$), 2.70—3.15 (m, 2H, $>\mathrm{C\underline{H}}$-O-$\mathrm{C\underline{H}}<$), 4.03 (d, 2H, $J = 6$ Hz, $\mathrm{C\underline{H}_2OTs}$), 7.25 (d, 2H, $J = 8$ Hz, $\mathrm{CH_3C_6\underline{H}_4}$), and 7.73 (d, 2H, $J = 8$ Hz, $\mathrm{CH_3C_6\underline{H}_4}$). Found: C, 65.08; H, 8.76%. Calcd for $C_{20}H_{32}O_4S$: C, 65.18; H, 8.75%.

(±)-Disparlure (5). To a mixture of CuI (209 mg, 1.1 mmol) and dry ether (10 ml) was slowly added 2.3 ml (2.2 mmol) of 0.96 M 4-methylpentyllithium in ether at −22°C. After the mixture was stirred for 20 min at −20°C, a solution of **12** (76 mg, 0.21 mmol) in dry ether (4 ml) was added dropwise. The mixture was stirred for 20 min; then the ice bath was removed. After saturated NH_4Cl (15 ml) was added, the mixture was stirred for 30 min. The organic materials of the filtrate were extracted with ether three times and the combined extracts were washed with brine and dried over $MgSO_4$. Removal of the solvent gave 101 mg of an oil which was chromatographed on SiO_2 (hexane-acetone, 30 : 1) to afford 53 mg (89%) of **5**: TLC (hexane-acetone, 3 : 1), $R_f = 0.81$. The IR and ^{1}H NMR data were identical with those of the literature.[7]

X-Ray Analysis of 4b. A crystal of dimensions 0.4×0.3 ×0.2 mm obtained from ethyl acetate-ether, was used for intensity measurement. Intensity data were obtained on a Rigaku AFC-5R diffractometer with graphite monochromatized Cu$K\alpha$ radiation, and using the θ—2θ scan technique ($2\theta \leqslant 128°$). The space group was approximated to be close to $P2_1/c$; however, a small number of very weak $0\ k\ 0$ and $h\ 0\ l$ reflections were observed for which $k \neq 2n$ and $1 \neq 2n$. The data were corrected for Lorentz and polarization effects but not for absorption. Among the 1014 unique reflection collected, 926 were considered to be observed at the 2.0 σ (F_o) level. Crystal data: $C_{12}H_{14}O_2Cl_2$, $Mr = 261.2$. Monoclinic, $P2_1/c$, $a = 6.858$ (1), $b = 9.630$ (3), $c = 9.307$ (4) Å, $\beta = 92.74$ (3)°, $U = 614.0$ Å^3, $Z = 2$, $Dx = 1.41$ g cm^{-3}. The structure was solved by direct method with MULTAN78 and refined by block-diagonal least-square methods. Positions of the hydrogen atoms were estimated from standard geometry. Final refinements with anisotropic temperature factors for the non-hydrogen atoms were reduced the R to 0.096.

The final atomic parameters, the full list of bond lengths and angles, and the F_o-F_c data have been deposited at the Chemical Sodiety of Japan (Document No. 8742).

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