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3-BUTENE-1,2-DIOL : AN ATTRACTIVE PRECURSOR FOR THE SYNTHESIS OF ENANTIOMERICALLY PURE ORGANIC COMPOUNDS

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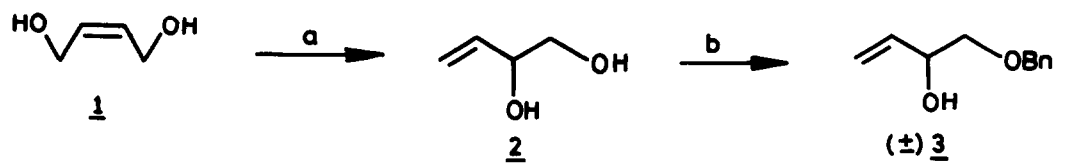
Abstract 3-Butene-1,2-diol obtained by the isomerization of cis-butene-1,4-diol has been transformed into several chiral building blocks.

Small and polyfunctional chiral building blocks form a backbone of research in the area of natural product chemistry. Introduction of new chiral building blocks with a wide range of applications or synthetic modification of existing proven molecules are currently undergoing intensive studies[1]. A large number of such molecules have been derived from naturally occurring compounds like carbohydrates, amino acids or hydroxy acids albiet in relatively long synthetic sequences. However, stereocontrolled asymmetric construction of these molecules with one or more asymmetric centers could be effected with a shorter synthetic pathway[2].

Commercially available cis-2-butene-1,4-diol (**1**) has been explored as a valuable precursor in natural product synthesis[3]. Although the one step isomerization of **1** into 3-butene-1,2-diol (**2**) is known for a long time, **2** was prepared recently by a long synthetic route[4], perhaps due to the difficulty in responding to the patent procedure[5]. It appeared to us that if **2** is to be realised as an attractive building block, the isomerization of **1** into **2** should be reexamined (Scheme 1). In this paper we wish to describe a) an improved procedure of isomerization of **1**; b) the kinetic resolution of the benzyloxy derivative **3** by Sharpless asymmetric epoxidation and c) some application of derived chiral building blocks for the synthesis of organic compounds.

Scheme 1



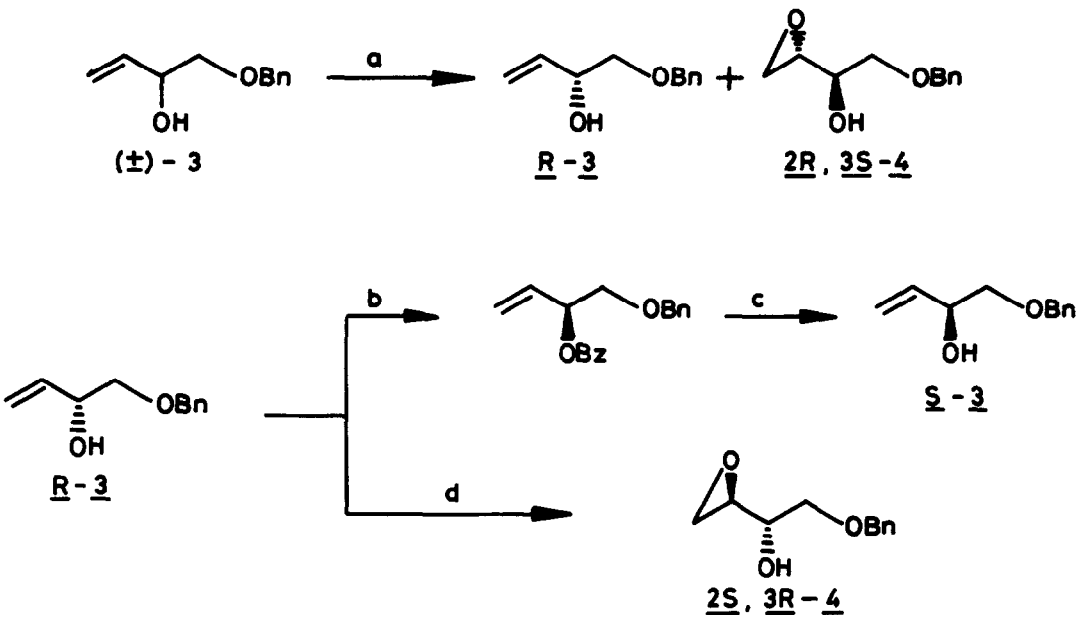
1 **2** **(±) 3**

a $HgSO_4$, H_2SO_4, H_2O, Δ, 1.5h **b** NaH, BnBr, THF, R.T., 2h.

Thus, compound **3** was obtained by selective monobenzylation of **2** with each one equivalent of sodium hydride and benzyl bromide in THF in 70% yield. Subsequent kinetic resolution of **3** under Sharpless epoxidation conditions[6] with tert-butylhydroperoxide (TBHP) and (-) diisopropyltartrate (DIPT) in methylene chloride at -20°C proceeded well to furnish simultaneously (2R,3S)-1-benzyloxy-3,4-epoxybutan-2-ol (**4**) and (R)-1-benzyloxy-3-buten-2-ol (**3**) which are

expected to serve as good precursors for the synthesis of polyhydroxylated chiral building blocks. Although (2R,3S)-4 and (R)-3 have both been synthesised independently[7,8] by long synthetic routes starting from (+)-tartaric acid, certainly the present synthetic modification to obtain 3 and 4 in just two steps from 2 was a significant improvement. Interestingly the isomeric (S)-3 was also prepared from (R)-3 by employing reagents, diethylazodicarboxylate (DEAD), triphenylphosphine (TPP) and benzoic acid in accordance with the conditions of the Mitsunobu reaction[9] followed by debenzoylation with methanolic sodium methoxide. Likewise, the isomeric (2S,3R)-4 was also prepared by asymmetric epoxidation of (R)-3 by using (+)-DIPT as a chiral auxiliary in 86% yield (Scheme 2). The utilisation of the isomeric 3 and 4 for the synthesis of (S)-2-aminobutanol (7) β -lactam intermediate (11), (4S,5R)-5-hydroxy-4-decanolide (L-factor, 18), the proposed autoregulator for leukaemomycin biosynthesis and the chiral aldehyde intermediate (15) are discussed.

Scheme 2

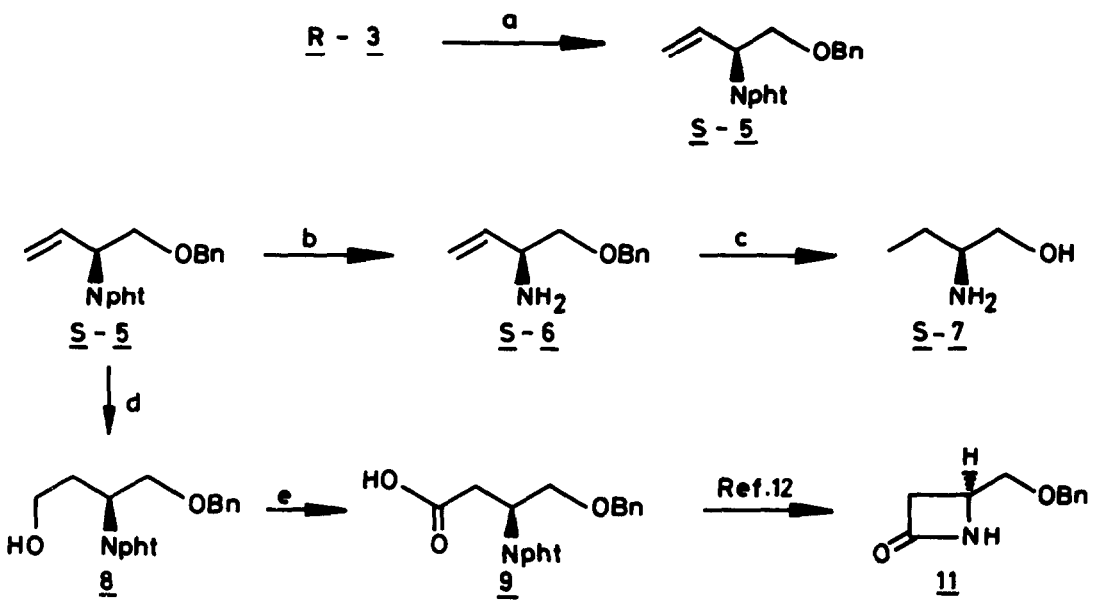


a TTIP, (−) DIPT, TBHP (0.6eq.), CH_2Cl_2, -20°C, 26h; b DEAD, TPP, C_6H_5COOH, 2h ; c NaOMe, MeOH; d TTIP, (+) DIPT, TBHP, CH_2Cl_2, − 20°C .

Reaction of (R)-3 with phthalimide in the presence of DEAD and TPP in THF at room temperature afforded the expected vinylglycinol[10] derivative (5) in 79% yield. Subsequent treatment of 5 with hydrazine hydrate in refluxing ethanol gave 6 which on exhaustive reduction over palladised charcoal at 50 psi furnished (S)-2-aminobutanol (7)[11]. Consequently, the intermediate (5) was subjected to hydroboration with 9-borabicyclononane (9-BBN) followed by oxidation to give the alcohol (8) in 85% yield. Oxidation of the hydroxymethyl group of 8 with Jones oxidation furnished the acid 9. Treatment of 9 with hydrazine hydrate followed by the

cyclization is reported to give the (S)-β-lactam derivative (11)[12] (Scheme 3).

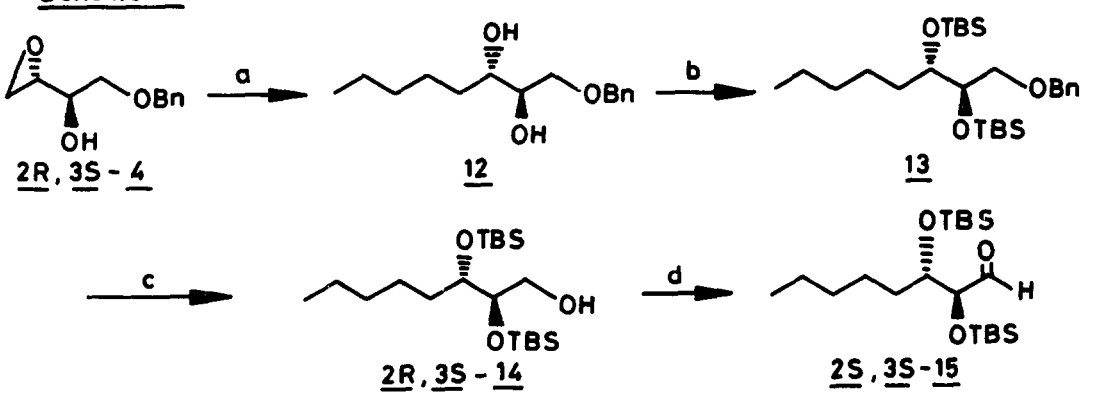
Scheme 3



a DEAD, TPP, Phthalimide, THF; b $NH_2NH_2 \cdot H_2O$, EtOH, Δ, 15 min.; c Pd-c, H_2, 50 psi; d 9-BBN, NaOH, H_2O_2, 0°C; e Jones oxid.

The chiral (2S,3S)-aldehyde (15) has been used as a valuable intermediate[13] in the synthesis of lipoxin B (Scheme 4). Treatment of (2R,3S)-4 with dibutyllithium cuprate at -78°C opened the epoxide ring to furnish 12 in 80% yield. The diol 12 was protected as tert-butyldimethylsilyl ether (13) with TBS chloride in the presence of dimethylaminopyridine, triethylamine in methylene

Scheme 4

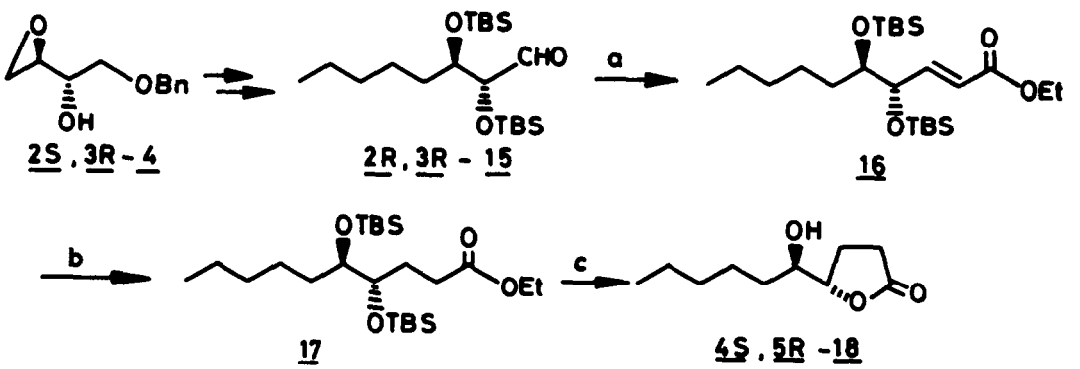


a BuLi, CuI, -78°C, 2h; b TBDMSCl, Et_3N, DMAP, CH_2Cl_2; c Pd-c, H_2, EtOAc. d $(COCl)_2$, DMSO, Et_3N, -78°C

chloride. The removal of the benzyl group of **13** by hydrogenolysis (**14**) followed by Swern oxidation with oxalylchloride, DMSO, triethylamine furnished **15** in 85% yield.

On the basis of above sequence of reactions the isomer (2S,3R)-**4** was transformed into the (2R,3R)-**15**. Subsequent Wittig reaction of (2R,3R)-**15** with carboethoxymethylenetriphenylphosphorane in benzene gave the α,β-unsaturated derivative (**16**) in 76% yield. Reduction of the double bond of **16** gave **17** which on treatment with tetra-n-butylammonium fluoride in THF gave (4S,5R)-L-factor (**18**)[14] (Scheme 5).

Scheme 5



a $Ph_3P{=}CHCO_2Et$, benzene, 80°C, 2h ; b Pd-c, H_2, EtOH ; c Bu_4NF, THF, 4h

Experimental

FT-IR spectra were determined as neat films or as solutions in $CHCl_3$ using a Perkin-Elmer 683 spectrometer. ^{1}H-NMR spectra were obtained on Varian FT-80 or Bruker WH-90 spectrometer in $CDCl_3$ containing TMS as an internal standard with chemical shifts (δ) expressed in ppm down field from TMS. Optical rotations were measured on a Jasco DIP 360 polarimeter. Mass spectra were run on AEI MS 30 or CES 21-110 B spectrometer.

(±)-3-Butene-1,2-diol (2)

A mixture of 2-butene-1,4-diol (**1**) (60 g, 0.68 mol), water (25 ml), concentrated sulphuric acid (0.35 ml) and mercuric sulphate (0.25 g) was heated under reflux. After 1.5 h (t.l.c., Merck precoated silica gel plate : ethylacetate : methanol : chloroform; 6:1:6, R_f for (**1**) 0.36; R_f for (**2**) 0.49), the reaction mixture was cooled to 0°C and neutralized with 10% sodium hydroxide to pH 7. The contents of the flask were distilled by using a 12" Vigreux fractionating column. The first fraction boiled between 38-43°C/15 mm contained water, second fraction collected between 78-90°C/15 mm contains 3-butene-1,2-diol (**2**) (37 g, 62%) as a colourless liquid and subsequently, third fraction obtained has traces of unreacted **1** at 110-115°C/15 mm. ^{1}H NMR

($CDCl_3$) :δ3.5 (s, 2H, OH exchanges with D_2O), 3.5-4.5 (m, 3H, H-1, 1', H-2), 5.05-6.10 (m, 3H, CH_2=CH).

(±)-1-Benzyloxy-3-buten-2-ol (3)

To compound **2** (7.04 g, 0.08 mol) in THF (250 ml) was added sodium hydride (4.0 g, 0.08 mol, 50% dispersion in oil) under nitrogen. The reaction mixture was cooled to -20°C and then benzyl bromide (13.68 g, 0.08 mol) in dry THF (50 ml) was added. After stirring at room temperature for 5 h, the reaction mixture was concentrated, diluted with CH_2Cl_2, washed with water, dried (Na_2SO_4) and concentrated. The residue was purified on silica gel column with ethyl acetate-light petroleum (1:2) as eluant to afford **3** (9.97 g, 70%) as an oil. ν_{max}: 3450 cm^{-1}; ^1H NMR ($CDCl_3$) : δ 2.3 (s, 1H, D_2O exchangeable); 3.25-3.65 (m, 2H, H-1, 1'), 4.32 (m, 1H, H-2), 4.55 (s, 2H, OCH_2Ph), 5.1-6.0 (m, 3H, $CH=CH_2$), 7.23 (s, 5H, Ph); MS : m/z = 178 (M^+), 161, 91 (100%).

Kinetic resolution of (±)-1-benzyloxy-3-buten-2-ol (3) by Sharpless asymmetric epoxidation

To a solution of titanium (IV) isopropoxide (4.31 ml, 14.5 mmol), (-) diisopropyl-D-tartrate (4.07 g, 17.4 mmol) in CH_2Cl_2 at -20°C was added (±) **3** (2.55 g, 14.3 mmol) followed by tert. butylhydroperoxide (7.24 mmol, 4.8 M in isooctane). After 26 h at -20°C, the reaction mixture was worked up in usual manner. The residue was chromatographed on silica gel with ethyl acetate-light petroleum (1:5) as eluant to afford the (R)-**3** (0.95 g, 75%) which was distilled under vacuo, b.p. 130°C/5 mm, $[\alpha]_D$ + 5.9° (c, 1.77, $CHCl_3$), lit.[8] $[\alpha]_D$ + 6.2° (c, 1.6, $CHCl_3$).

The second fraction from the column afforded (2R,3S)-**4** (1.15 g, 83%), which was distilled under vacuo, b.p. 138-140°C/5 mm, $[\alpha]_D$ -10.4° (c, 1.24, $CHCl_3$), lit.[7] $[\alpha]_D$ -11° (c, 0.93, $CHCl_3$).

(2S)-1-Benzyloxy-3-butene-2-ol (3)

To a mixture of (R)-**3** (3.98 g, 22.4 mmol), triphenylphosphine (8.24 g, 31.4 mmol), benzoic acid (3.82 g, 31.3 mmol) in dry THF (20 ml) was added diethylazodicarboxylate (5.46 g, 31.4 mmol). The reaction was stirred at room temperature for 2 h and concentrated. The residue was chromatographed on silica gel with ethyl acetate-light petroleum (1:2) as eluant to afford the benzoate which was dissolved in methanol (20 ml) and sodium metal (30 mg) was added. After 30 min the reaction mixture was deionised with Amberlite IR 120(H) resin, filtered and the solution was concentrated and chromatographed to afford (S)-**3** (3.43 g, 86%) as a colourless liquid, $[\alpha]_D$ -5.9° (c, 0.5, $CHCl_3$). Analysis Calc. for $C_{11}H_{14}O_2$: C, 74.1; H, 7.86; Found : C, 73.9; H, 7.74%.

(2S,3R)-1-Benzyloxy-3,4-epoxy-2-butanol (4)

To a stirred dry CH_2Cl_2 (100 ml) at -20°C under N_2 were successively added, Ti $(Opr)_4$ (2.81 g, 9.9 mmol), (+)-diisopropyl-L-tartrate (2.31 g, 9.9 mmol), (R)-3 (1.7 g, 9.5 mmol) and a solution of TBHP in CH_2Cl_2 (3.1 N, 6.5 ml). The mixture was stored at -20°C for 18 h. The temperature was raised to room temperature and the reaction mixture was diluted with ether and sat. sodium sulphate. The mixture was stirred vigorously for 2 h at room temperature and filtered. The filtrate was concentrated and the residue was chromatographed over SiO_2 to give (2S,3R)-4 (1.6 g, 86%) as an oil, $[\alpha]_D$ + 9.2° (c, 4.5, $CHCl_3$), lit.[7] $[\alpha]_D$ + 10.0° (c, 0.68, $CHCl_3$).

(S)-1-Benzyloxy-2-N-phthalimido-3-butene (5)

Diethylazodicarboxylate (2.97 g, 17.0 mmol) in tetrahydrofuran (8 ml) was added dropwise to a solution of (R)-3 (3.02 g, 17.0 mmol), phthalimide (2.51 g, 17.0 mmol) and triphenylphosphine (4.55 g, 17.4 mmol) in THF (20 ml) at room temperature. After 5 h, solvent was removed and the residue was purified by a silica gel column with ethyl acetate-light petroleum (1:19) as eluant to give 5 (4.1 g, 79%) as thick syrup, $[\alpha]_D$ -4.6° (c, 1.0, $CHCl_3$), ν_{max} : 3000, 1770, 1730, 1550, 1400, 1100 cm^{-1}; ^1H NMR ($CDCl_3$) : δ 3.37 (dd, 1H, J = 9 Hz and 6.5 Hz, H-1a), 4.01 (dd, 1H, J = 9 Hz, H-1b), 4.50 (s, 2H, $C\underline{H}_2$-Ph), 5.0-5.5 (m, 3H, H-4, 4' and H-2), 6.25 (m, 1H, H-3), 7.23 (s, 5H, Ph), 7.7-8.0 (m, 4H, aromatic). Analysis Calc. for $C_{19}H_{17}NO_3$: C, 74.3; H, 5.5; N, 4.6; Found : C, 74.1; H, 5.75; N, 4.35%.

(S)-(+)-2-Amino-1-butanol (7)

Compound 5 (1.0 g, 3.25 mmol) and hydrazine hydrate (0.19 g) in ethanol (10 ml) was heated under reflux for 15 min. Conc. HCl was added and solid residue filtered. The filtrate was concentrated and repeatedly boiled with aqueous ethanol. The combined extracts was concentrated and made basic with 1N aqueous NaOH and again extracted with ether. The ethereal layer was dried (Na_2SO_4), concentrated and residue purified by column chromatography on SiO_2 with methanol : chloroform (1:19) as eluant to obtain (S)-1-benzyloxy-2-amino-3-butene (6) (0.4 g, 69%) as an oil, $[\alpha]_D$ -16.5° (c, 1.2, $CHCl_3$), ν_{max} : 3460 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.62 (s, 2H, NH_2 exchanges with D_2O), 3.25 (m, 1H, H-2), 3.98 (m, 2H, H-1, 1'), 4.6 (s, 2H, $C\underline{H}_2$Ph), 5.1-6.23 (m, 3H, CH_2=CH), 7.26 (s, 5H, Ph).

To a solution of 6 (0.22 g, 1.24 mmol) in ethanol was subjected to reduction over palladium on carbon (35 mg) at 50 psi. After 5 h the catalyst was filtered through celite, concentrated to obtain 7 (95 mg, 86%) as thick syrup, $[\alpha]_D$ + 9.4° (c, 1.2, ethanol), lit.[11] $[\alpha]_D$ + 10.1° (neat); ν_{max} 3440, 3350, 2750, 2150 cm^{-1}; ^1H NMR ($CDCl_3$) : δ 0.95 (t, 3H, CH_3), 1.63 (m, 2H, CH_2), 3.05 (bs, 2H, NH_2 exchanges with D_2O), 3.3-3.7 (m, 3H, H-1, 1' and H-2), 4.25 (s, 1H, OH).

(R)-4-Benzyloxy-3-N-phthalimide-butanoic acid (9)

To a solution of **5** (1.4 g, 4.56 mmol) in THF (10 ml) at 0°C was added 9-BBN (0.74 g, 3.02 mmol) in THF. After 5 h at room temperature, the reaction was treated with water (1.5 ml), NaOH solution (1.6 g of NaOH in 5 ml of H_2O) and 30% H_2O_2 (6 ml). The resultant mixture was heated at 55°C for 1 h with constant removal of THF and the residue was partitioned between ethyl acetate and brine solution. The organic phase was washed with brine, dried and concentrated to give a residue which was chromatographed on SiO_2 with MeOH-$CHCl_3$ (2:98) as eluant to give the alcohol **8** (1.26 g, 85%) as a light yellow oil, $[\alpha]_D$ + 12.7° (c, 1.0, $CHCl_3$), ν_{max} : 3440, 1770, 1728 cm^{-1}; ^1H NMR ($CDCl_3$) : δ 1.75 (m, 2H, H-3, 3'); 3.5-4.05 (m, 4H, CH_2), 4.25 (m, 1H, C<u>H</u>-NPht), 4.57 (s, 2H, C<u>H</u>$_2$-Ph), 7.21 (s, 5H, Ph), 7.7-8.0 (m, 4H, aromatic).

Compound **8** (0.41 g, 1.26 mmol) in 20 ml of acetone was treated with excess of Jones reagent (prepared from CrO_3 : H_2SO_4 : H_2O). After stirring for 30 min at 0°C the unreacted reagent was destroyed by the addition of isopropanol. The mixture was then filtered, concentrated chromatographed on SiO_2 with MeOH-$CHCl_3$ (2:98) to give **9** (0.29 g, 68%) as thick syrup, $[\alpha]_D$ + 18.2° (c, 1.85, $CHCl_3$), lit.[12] $[\alpha]_D$ + 19.7° (c, 2.52, $CHCl_3$), ν_{max} : 3500, 1775, 1720 cm^{-1}. ^1H NMR ($CDCl_3$) : δ 2.52 (bs, 1H, OH), 3.62 (m, 2H, CH_2), 4.3 (m, 3H, H-2, 2' and H-3), 4.6 (s, 2H, -OC<u>H</u>$_2$Ph), 7.2 (s, 5H, Ph), 7.6-7.9 (m, 4H, aromatic).

(2R,3S)-1-Benzyloxy octane diol (12)

n-Butyllithium in hexane (6.5 ml, 20.6 mmol, 3.2N) was added dropwise to a stirred suspension of CuI (2.09 g, 11 mmol) in dry THF (30 ml) at -78°C. After 30 min **4** (1.06 g, 5.5 mmol) in THF (5 ml) was slowly added. The mixture was stirred at -78°C for 1 h, then treated with saturated NH_4Cl/NH_4OH for 30 min, extracted with ethyl acetate, dried and concentrated. The residue was purified by column chromatography on silica gel with ethyl acetate : light petroleum (2:1) to give **12** (1.04 g, 80%) as a colourless oil, $[\alpha]_D$ -2.75° (c, 0.45, $CHCl_3$). ν_{max} : 3420 cm^{-1}. ^1H NMR ($CDCl_3$) : δ 0.98 (t, 3H, CH_3); 1.25-1.5 (m, 8H, 4 x CH_2), 2.2 (bs, 2H, OH), 3.5-3.7 (m, 4H), 4.5 (s, 2H, C<u>H</u>$_2$-Ph), 7.3 (bs, 5H, Ph). Analysis Calc. for $C_{15}H_{24}O_3$: C, 71.4; H, 9.5; Found : C, 71.05; H, 9.2%.

(2R,3S)-2-Bis(tert. butyldimethylsiloxy)-1-benzyloxy octane (13)

Compound **12** (0.72 g, 2.85 mmol) was stirred with triethylamine (1.7 ml) and dimethylaminopyridine (14 mg) in dry dichloromethane (20 ml) under nitrogen. Tert. butyldimethylsilyl chloride (1.27 g, 8.4 mmol) was added. After 16 h at room temperature solvents were removed and the residue was diluted with ethyl acetate. The solid was filtered, the filtrate concentrated to a thick syrup and then chromatographed on silica gel using ethyl acetate : light petroleum (1:19) as eluant to give **13** (1.2 g, 82%), $[\alpha]_D$ -5.2° (c, 0.63, $CHCl_3$), ^1H NMR ($CDCl_3$) : δ 0.07

(m, 12H, 2Si $(CH_3)_2$), 0.85 (m, 21H, 2Si-C_4H_9-t, CH_3), 1.2-1.5 (m, 8H, CH_2), 3.5-3.8 (m, 2H, CH), 3.9 (m, 2H, CH_2), 4.5 (s, 2H, $\underline{CH_2}$-Ph), 7.2 (m, 5H, Ph). Analysis Calc. for $C_{27}H_{52}O_3Si_2$: C, 67.5; H, 10.8; Found : C, 6.7.02; H, 10.62%.

(2R,3S)-2,3-Bis(tert. butyldimethylsiloxy)-1-hydroxy octane (14)

Compound **13** (0.40 g, 0.83 mmol) in ethanol (10 ml) containing 10% palladium-on-carbon (15 mg) was stirred under an atmosphere of hydrogen at normal pressure and temperature for 5 h. The catalyst was filtered through a pad of celite, washed with ethanol and then concentrated to afford **14** (0.27 g, 83%) as a thick syrup, $[\alpha]_D$ + 6.0° (c, 0.56, $CHCl_3$), lit.[13] $[\alpha]_D$ +5.8° (c, 1.0, $CHCl_3$), ν_{max} : 3400 cm^{-1}.

(2S,3R)-2,3-Bis(tert.butyldimethylsiloxy) octanal (15)

A solution of oxalyl chloride (0.088 g, 0.69 mmol) and dry dimethylsulfoxide (0.109 g, 1.39 mmol) in dry methylene chloride (15 ml) was cooled to -78°C and then a solution of **14** (0.195 g, 0.5 mmol) in CH_2Cl_2 was added. After 30 min triethylamine (0.3 ml) was added. The -78°C cooling bath was then replaced with a -30°C bath, and the mixture stirred for 1 h. It was then diluted with pentane (50 ml), washed with sodium bisulfate, water, dried, concentrated below 35°C. The residue was purified by SiO_2 with n-pentane to furnish **15** (0.165 g, 85%) as an oil, $[\alpha]_D$ + 2.4° (c, 1.5, $CHCl_3$), lit.[13] $[\alpha]_D$ + 2.7° (c, 1.0, $CHCl_3$); ν_{max} : 2940, 1740, 1130 cm^{-1}. ^1H NMR ($CDCl_3$) : δ 0.04 (s, 12H, 2Si$(CH_3)_2$, 0.87 (s, 21H, 2Si-C_4H_9-t, CH_3), 1.2-1.72 (m, 8H), 3.85 (dt, 1H, J = 7.6 Hz, 4.4 Hz, CH), 4.01 (dd, 1H, J = 4.4 Hz, 0.7 Hz, CH), 9.76 (d, 1H, J = 0.7 Hz, CHO).

Compounds (2$\underline{S}$,3$\underline{R}$)-**12**, (2$\underline{S}$,3$\underline{R}$)-**13**, (2$\underline{S}$,3$\underline{R}$)-**14** and (2$\underline{R}$,3$\underline{R}$)-**15** were synthesised by the same procedures as described above and characterised by comparison of physical and spectral data with the corresponding isomers.

Ethyl (2E,4S,5R)-4,5-Bis(tert.butyldimethylsiloxy) decenoate (16)

Compound (2$\underline{R}$,3$\underline{R}$)-**15** (0.20 g, 0.51 mmol), carbethoxymethylenetriphenylphosphorane (0.20 g, 0.57 mmol) in dry benzene was heated under reflux for 1 h under nitrogen. The reaction mixture was concentrated and the residue was chromatographed on silica gel with light petroleum as eluant to give **16** (0.18 g, 76%) as a colourless oil , $[\alpha]_D$ + 2.3° (c, 2.4, $CHCl_3$), ν_{max} : 1735 cm^{-1}, ^1H NMR ($CDCl_3$) : δ 0.04 (s, 12H, 2Si$(CH_3)_2$, 0.87 (s, 21H, 2Si-C_4H_9-t, CH_3), 1.2-1.72 (m, 11H), 3.85 (dt, 1H, J = 7.6 Hz, 4.4 Hz, CH), 4.01 (dd, 1H, J = 4.4 Hz, 0.7 Hz, CH), 4.23 (q, 2H, J = 7 Hz, CH_2), 5.9 (d, 1H, J = 15 Hz, H-2), 7.5 (dd, 1H, J = 15 Hz, H-3). Analysis Calc. for $C_{24}H_{50}O_4Si_2$: C, 62.8; H, 10.9; Found : C, 62.5; H, 10.8%.

(4S,5R)-5-Hydroxy-4-decanolide (18)

Compound **16** (0.17 g, 0.37 mmol) and palladium on carbon (30 mg) in ethanol (3 ml) was hydrogenated at normal pressure and temperature for 2 h. The catalyst was filtered through celite and concentrated to give crude **17** which was diluted with THF (1 ml) and treated with 1M tetrabutylammonium fluoride (0.7 ml) for 4 h. It was partitioned between water and ether. The ethereal layer was washed with brine, dried and concentrated to afford a residue which was chromatographed on SiO_2 with ethyl acetate : light petroleum (2:5) to afford **18** (0.03 g, 44%) as a thick syrup, $[\alpha]_D$ + 10.2° (c, 1.5, $CHCl_3$), lit.[14] $[\alpha]_D$ + 11° (c, 0.7, $CHCl_3$); ν_{max} : 3470, 1770 cm^{-1}. ^1H NMR ($CDCl_3$) : δ 0.90 (t, 3H, CH_3), 1.2-2.7 (m, 13H, $2CH_2$, OH), 3.6 (m, 1H, H-5), 4.0-4.5 (m, 1H, H-4).

References and Notes

1. J.W. Scott, Asymmetric Synthesis, ed by J.D. Morrison, Academic Press, New York (1984), Vol. 4, Chap. 1.
2. a) A. Vasella, Modern Synthetic Method, ed by R. Scheffold, Otto Salle Verlag, Frankfurt am Main (1980), Vol. 2, P. 173; b) D. Seebach and E. Hungerbuhler, ibid, P. 91; c) S. Hanessian, The Total Synthesis of Natural Products : the 'Chiron' Approach, Organic Chem. series, Vol. 3, Pergamon Press, Oxford (1983); d) Asymmetric Synthesis, ed by G.M. Coppola, H.F. Schuster, John Wiley & Sons (1987); e) T.D. Inch, Tetrahedron, **40**, 3161 (1984).
3. a) D. Tanner and P. Somfai, Tetrahedron, **43**, 4395 (1987); b) Y. Yabe, D. Guillaume and D.H. Rich, J. Am. Chem. Soc., **110**, 4043 (1988); c) C. Bonini and R.D. Fabio, Tetrahedron Lett., **29**, 815 (1988).
4. R.D. Walkup and R.T. Cunningham, Tetrahedron Lett., **28**, 4019 (1987).
5. R.J. Bloomfield, Chem. Abstr., **53**, 4140g (1959).
6. U.S. Martin, S.S. Woodard, T. Katsuki, Y. Yamada, M. Ikeda and K.B. Sharpless, J. Am. Chem. Soc., **103**, 6237 (1981).
7. a) V.E. Hungerbuhler and D. Seebach, Helv. Chim. Acta., **64**, 687 (1981); b) S. Takano, S. Kurotaki, Y. Sekiguchi, S. Satott, M. Hirama and K. Ogasawara, Synthesis, 811 (1988).
8. A.V. Rama Rao, E. Rajarathnam Reddy, B.V. Joshi and J.S. Yadav, Tetrahedron Lett., **28**, 6497 (1987). For recent synthesis : S. Takano, S. Tomita, Y. Iwabuchi, K. Ogasawara, Synthesis, 610 (1988); M. Kusakabe, H. Kato and F. Sato, Chemistry Lett., 2163 (1987).
9. O. Mitsunobu, Synthesis, 1 (1981).
10. a) Y. Ohfune and N. Kurokawa, J. Am. Chem. Soc., **108**, 6041 (1986); b) Y. Ohfune and N. Kurokawa, Tetrahedron Lett., **25**, 1071 (1984).
11. F. Fvanealanci, P. Cesti, W. Cabri, D. Bianchi, T. Martinengo and M. Foa, J. Org. Chem., **52**, 5709 (1987).

12. S. Takano, C. Kasahara and K. Ogasawara, Chemistry Lett., 175 (1983).
13. K.C. Nicolaou and S.E. Webber, Synthesis, 453 (1986).
14. K. Mori and T. Otsuka, Tetrahedron, **41**, 3253 (1985); J.S. Yadav, B.V. Joshi and M.K. Gurjar, Carbohydrate Res., **165**, 116 (1987) and references cited therein.

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