Synthesis of Optically Pure 2-Aziridinemethanols: Versatile Synthetic Building Blocks

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Synthesis of three *cis–trans* pairs of *N*-sulfonylated-2-aziridinemethanols starting from (*S*)-threonine, (*R*)-allothreonine, a chiral 2-amino alcohol, or enantiomerically enriched 2,3-epoxy alcohols is described. A synthetic route to *N*-tosyl- and *N*-mesyl-2-aziridinemethanols from (*R*)- and (*S*)-serines is also presented.

Keywords (*S*)-threonine; (*R*)-allothreonine; (*S*)-serine; (*R*)-serine; 2-aziridinemethanol; 2,3-epoxy alcohol

The aziridine ring framework can be found in a number of natural and synthetic compounds of biological importance.[1] Currently, there is significant interest in the synthesis and reaction of aziridines and their *N*-activated analogues.[2] The importance of optically active aziridines has led to efforts to develop useful synthetic methods for their construction.[3] The most frequently used procedure employs *N*-protected or unprotected serine derivatives.[4] Aziridines can also be synthesized by treatment of *O*-mesyl or *O*-tosyl derivatives of hydroxy amino acids with tertiary amines.[5] Optically active aziridines can be obtained by optical resolution of racemic compounds by chemical means.[6] Enantiomerically pure aziridines can also be synthesized from meso and racemic aziridines using enzymatic methods.[7] The cyclization of chiral 2-amino alcohols and their derivatives using Mitsunobu reagent is also an effective method for stereoselective aziridination.[8] Recently, the asymmetric synthesis of substituted aziridines from olefins has been developed.[9]

2-Aziridinemethanols **1** may be considered as aza-analogues of 2,3-epoxy alcohols **2** and they are versatile building blocks in the synthesis of biologically active compounds such as amino acids (both natural and unnatural),[10] amino alcohols,[11] sphinganine,[12] and antibiotics.[13] To date, however, 2,3-epoxy alcohols **2** are more widely used than their aza-analogues **1**.[14] This difference may be ascribed to the different availability of the two ring systems.

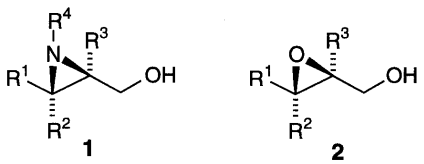
As part of an ongoing project aimed at the development of biologically active unusual amino acids, we required a series of *N*-tosyl- or *N*-mesyl-2-aziridinemethanols with defined stereochemistries. Described herein are the syntheses of *N*-sulfonylated 2-aziridinemethanols starting from amino acids, enantiomerically enriched 2,3-epoxy alcohols, or chiral 2-amino alcohols.

Results and Discussion

It is well known that the reactivity of NH-aziridines toward nucleophilic reagents is relatively low. Thus, activation by the introduction of an electron-withdrawing protecting group on the ring nitrogen atom of the aziridine is required. The term "activated aziridines" has been introduced by Ham for aziridines that easily undergo nucleophilic S*N*2-type ring-opening in the absence of a positive charge on the nitrogen atom.[15] The *p*-toluenesulfonyl or methanesulfonyl group serves as a most effective activating group.[16] The possible positions for attack by nucleophiles are C-2 or C-3 of the activated 2-aziridinemethanols. The regioselectivity of this ring opening reaction is expected to be controlled by a delicate balance of steric and electronic factors. In this context, three *cis–trans* pairs of *N*-tosyl-3-substituted-2-aziridinemethanols as well as two serine-derived 2-aziridinemethanols were synthesized.

Synthesis of a *cis–trans* Pair of *N*-Tosyl-3-methyl-2-aziridinemethanols 6 and 22 As shown in Chart 2, the known *N*-trityl aziridine **4**,[17] prepared in high yields from (*S*)-threonine **3**, was reduced with diisobutylaluminum hydride (DIBAL) to yield the 2-aziridinemethanol **5** (>99% ee)[18a] in 84% yield. Deprotection of the trityl group in **5** followed by tosylation gave *N*-tosyl 2-aziridinemethanol **6** (>98% ee)[19] in 60.9% yield. In a similar manner, *N*-mesyl 2-aziridinemethanol **7** [>98% ee,[18b] (the enantiomeric excess (ee) value was determined by conversion into the (*R*)-α-methoxy-α-(trifluoromethyl)phenylacetic acid ((*R*)-MTPA) ester) (chiralcel OD and ^{1}H-NMR)] was synthesized from **5** (>98% ee)[18b] in 32% yield.

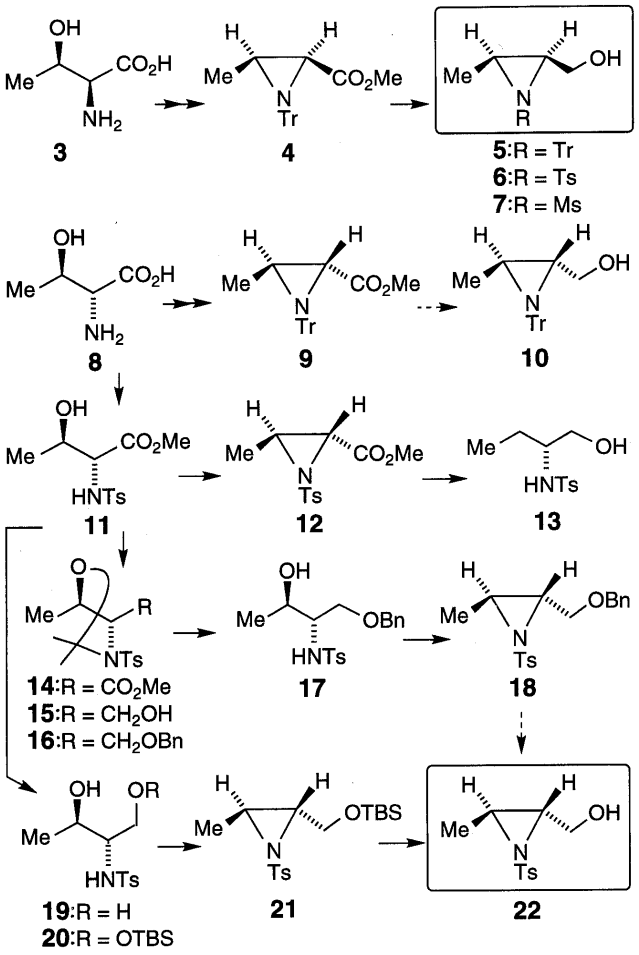
Synthesis of an isomer **22** of **6** proved considerably more troublesome than first envisioned. Various standard routes were attempted unsuccessfully. Thus, D-allothreonine **8** was successively treated with thionyl chloride–methanol, trityl chloride–triethylamine, and sulfuryl chloride–triethylamine[20] to afford the aziridine methyl ester **9** in 56.8% overall yield. Attempted reduction of the ester **9** with DIBAL failed to give the desired aziridinemethanol **10**. This failure was surprising in view of the successful reduction of the isomeric ester **4** under the same condi-



R^1, R^2, R^3 = H or alkyl, R^4 = H, Ts, or Ms

Ts = *p*-toluenesulfonyl
Ms = methanesulfonyl

Chart 1



Tr = trityl
Bn = benzyl
TBS = *tert*-butyldimethylsilyl

Chart 2

tions.

Next, reduction of the readily available *N*-tosyl aziridine **12** was attempted. The requisite aziridine methyl ester **12**, derived from D-allothreonine **8** *via* the *N*-tosyl methyl ester **11** in the usual way, was treated with DIBAL to yield a mixture of products from which only the undesired ring-opening product **13** was isolated as the major product in 32% yield. We have also tried to reduce **12** with either lithium aluminum hydride ($LiAlH_4$) or lithium borohydride ($LiBH_4$) but found that the yield of the desired aziridinemethanol **22** varied from 0% to 3% for reasons that were not clear.

Further, we decided to attempt the synthesis of the benzyl ether **18** in the hope that the benzyl group in **18** would be readily removable by catalytic hydrogenolysis. Thus, the benzyl ether **17**, which in turn was derived from the *N*-tosyl ester **11** by successive treatment with 2,2-dimethoxypropane–acetone–$BF_3 \cdot Et_2O$, DIBAL, benzyl bromide–sodium hydride (NaH), and 1 N methanolic hydrochloric acid, was transformed into the benzyloxy aziridine **18** by treatment with triphenylphosphine and diethyl azodicarboxylate. However, a number of standard reductive debenzylation methods did not produce the desired aziridine **22** but afforded a complex mixture of

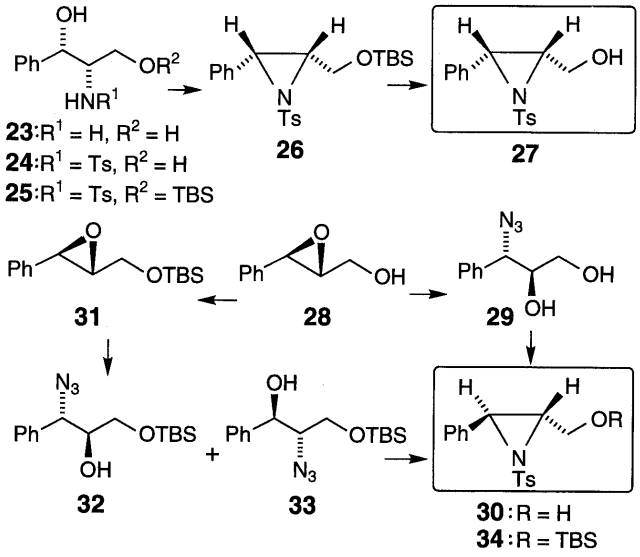


Chart 3

products.

From the above results, an appropriate choice of protecting group for the hydroxy group seemed essential. Therefore, we next examined the siloxy aziridine **21**, which should give rise to the desired 2-aziridinemethanol **22**. The siloxy aziridine **21** required for the synthesis of **22** was easily synthesized from the *N*-tosyl ester **11**. Selective silylation of the diol **19**, which in turn was derived from **11** by reduction with DIBAL, and the subsequent aziridine-ring formation by the use of triphenylphosphine yielded the 2-aziridinemethanol silyl ether **21**. Desilylation of **21** with tetrabutylammonium fluoride in tetrahydrofuran (THF) afforded the desired *N*-tosyl 2-aziridinemethanol **22** (>98% de)[18b,19] in 94.5% yield.

Synthesis of a *cis–trans* Pair of *N*-Tosyl-3-phenyl-2-aziridinemethanols 27 and 30 We studied this chemistry to open a route to the synthesis of new amino alcohols and unusual amino acids derivatives as shown in Chart 3.

3-Phenyl-2-aziridinemethanol **27** (>98% de)[18b] can be synthesized in high yield from the commercially available homochiral dihydroxyamine **23** *via* a four-step sequence involving (1) *N*-tosylation, (2) selective silylation, (3) aziridine-ring formation by triphenylphosphine, and (4) removal of the silyl protecting group.

An isomeric 3-phenyl-2-aziridinemethanol **30** was synthesized as follows. The dihydroxy azide **29** can easily be prepared from the 2,3-epoxy alcohol **28** by the use of the Sharpless protocol.[21] However, aziridine-ring closure of **29** using the triphenylphosphine and subsequent tosylation gave the 2-aziridinemethanol **30** in only 26% yield after flash chromatographic purification. All attempts to enhance the yield of **30** were to no avail. A more practical synthesis of **30**, which was appropriate for large-scale preparation, started with the silyl ether **31**. Reaction of the silyl ether **31**, derived from the 2,3-epoxy alcohol **28**, with sodium azide in the presence of ammonium chloride gave a readily separable mixture of azides **32** (85% yield) and **33** (13% yield). The protected aziridinemethanol **34** was synthesized in over 92% isolated yields from both azides **32** and **33** *via* two-step of reactions involving

reductive ring-closure with triphenylphosphine followed by *N*-tosylation with tosyl chloride–triethylamine. For practical purposes, a mixture of diastereomers **32** and **33** can be used for the formation of the aziridine **34**. Exposure of **34** to tetrabutylammonium fluoride in THF afforded the desired 2-aziridinemethanol **30** (>98% de)[18c,19] in 94% isolated yield.

Synthesis of a *cis–trans* Pair of *N*-Tosyl-3-benzyloxymethyl-2-aziridinemethanols 42 and 50 *N*-Tosyl-3-benzyloxymethyl-2-aziridinemethanols have enjoyed considerable attention recently as building blocks for the synthesis of biologically important compounds.[10a,11] Notable in this regard is the work of Tanner and collaborators.[13]

The siloxy epoxide **36** prepared from the known 2,3-epoxy alcohol **35**[20] (86% ee)[18b] was allowed to react with sodium azide in the presence of ammonium chloride[21] to yield a 1:1 mixture of two products. The mixture was separated by flash chromatography, yielding, in order of elution, **37** and **38**. At this stage, although the NMR spectra of these two isolated compounds were distinctively different, unequivocal structure determinations were not possible. The attached position of the azide group (and hence the position of the secondary hydroxy group) in **37** and **38** was unequivocally established by ^1H–^1H correlation spectroscopy (COSY) experiments on the diacetates **39** and **40**, which were derived from **37** and **38**, respectively. Although the separation of the two isomers **37** and **38** was conveniently accomplished by flash silica gel chromatography, the reaction of a mixture of **37** and **38** with triphenylphosphine yielded the protected aziridine **41** as the sole isolable product, which, upon exposure to tetrabutylammonium fluoride, yielded the expected 2-aziridinemethanol **42**. Although the ee of the starting epoxy alcohol **35** was only 86%, essentially optically pure 2-aziridinemethanol **42** (>98% ee)[18d] was obtained by recrystallization of the crude product from ether.

In a similar manner, the siloxy epoxide **44** derived from the known 2,3-epoxy alcohol **43**[22] was transformed into 2-aziridinemethanol **50**[13a] (>98% ee)[18d] *via* a three-step sequence of reactions involving (1) nucleophilic epoxide ring opening with sodium azide, (2) aziridine ring formation by means of triphenylphosphine, and (3) removal of the silyl protecting group by treatment with tetrabutylammonium fluoride. The attached position of the azide group in **45** and **46** was firmly established by ^1H–^1H COSY experiments on the diacetates **47** and **48**, which in turn were derived from **45** and **46**, respectively.

Activated 2-Aziridinemethanols Derived from (*R*)- and (*S*)-Serines We have also synthesized the simplest activated 2-aziridinemethanols **54** and **58**. Our approach is shown in Chart 5. The starting ester **51** was readily available from (*R*)-serine *via* a three-step sequence of reactions involving methylation with thionyl chloride in methanol, *N*-protection with tosyl chloride and triethylamine, and *O*-silylation with *tert*-butyldimethylsilyl chloride and imidazole. The ester **51** was allowed to react with DIBAL to yield a primary alcohol **52**, which, upon treatment with triphenylphosphine and diethyl azodicarboxylate, yielded the protected aziridine **53**. Finally, deprotection of the silyl group in **53** was accomplished by exposure to tetrabutylammonium fluoride in THF to

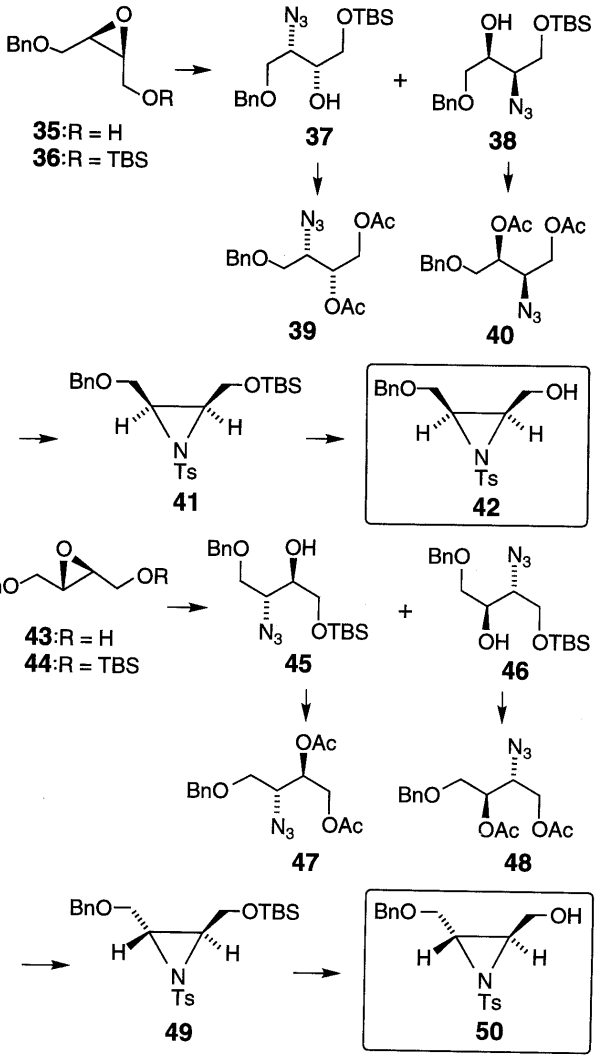


Chart 4

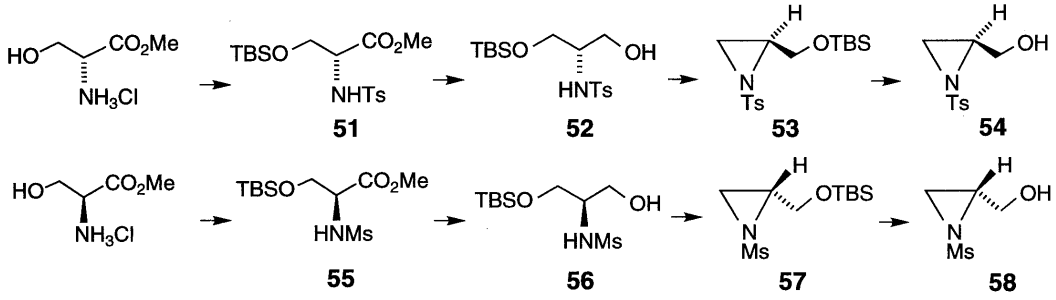


Chart 5

afford *N*-tosyl 2-aziridinemethanol **54** (>98% ee)[18b,19] in 99% yield.

In a similar manner, *N*-mesyl 2-aziridinemethanol **58** [>98% ee,[18b] (the ee value was determined by conversion into the (*S*)-(+)-MTPA ester)] was synthesized by starting from methyl (*S*)-*N*-mesyl-*O*-*tert*-butyldimethylsilylserinate **55** *via* the alcohol **56** and the protected aziridinemethanol **57**, as shown in Chart 5.

In summary, although the yields (see Experimental section) were not necessary optimized, the described method offers facile entry to activated 2-aziridinemethanols. We are now in a position to synthesize biologically important unusual amino acids as well as dipeptide isosteres. Utilization of the described aziridines for reaction mechanism studies, as well as synthesis of novel dipeptide isosteres, is currently under investigation in our laboratory .

Experimental

General Methods All reactions were carried out under a positive pressure of argon. All glassware and syringes were dried in an electric oven at 110 °C prior to use. All melting points were measured on a Yanagimoto melting point apparatus and are uncorrected. Nominal (low resolution (LR)) and exact (high resolution (HR)) mass spectra (MS) were recorded on a JEOL JMS-01SG-2 or JMS-HX/HX 110A mass spectrometer. The ^{1}H-NMR spectra were recorded on a JEOL FX-200, JNM-EX 270, or Bruker AC-300 spectrometer. Chemical shifts are reported in parts per million downfield from internal Me_4Si (s=singlet, d=doublet, dd=double doublet, ddd=doublet of double doublet, t=triplet, m=multiplet). Optical rotations were measured with a JASCO DIP-360 digital polarimeter. For flash chromatographies, Silica gel 60 H (silica gel for thin-layer chromatography, Merck) or Silica gel 60 (finer than 230 mesh, Merck) was employed.

(2*S*,3*S*)-2-Hydroxymethyl-3-methyl-1-tritylaziridine (5) DIBAL in *n*-hexane (140 ml, 0.21 mol; 1.5 M solution) was added dropwise to a stirred solution of the ester **4** (30 g, 83.9 mmol) in 170 ml of CH_2Cl_2 at −78 °C under argon. The mixture was allowed to warm to room temperature and stirring was continued for 3 h. The mixture was recooled to −78 °C, and a saturated NH_4Cl solution (50 ml) was added dropwise with vigorous stirring. The inorganic salts were removed by filtration through Celite. The filtrate was extracted with EtOAc, and the extract was washed with water and dried over $MgSO_4$. The usual work-up and flash chromatography over silica gel with *n*-hexane–EtOAc (3:1) gave a crystalline mass. Recrystallization from *n*-hexane–CH_2Cl_2 (9:1) gave 23.19 g (84% yield) of the title compound **5** as colorless crystals. mp 86—88 °C. $[\alpha]_D^{26}$ +16.5° (*c*=1.06, $CHCl_3$). IR ($CHCl_3$): 3600, 3450, 1592, 1480, 1441, 1086, 1061, 1015, 990, 628 cm^{-1}. ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.33 (3H, m), 1.44 (1H, m), 1.73 (1H, m), 3.82 (2H, m), 7.15—7.50 (15H, m). LR-MS (EI) *m/z*: 329 (M^+), 244, 243 (base peak), 183, 166, 165, 105, 77. HR-MS *m/z* Calcd for $C_{23}H_{23}NO$: 329.1778. Found: 329.1775. *Anal.* Calcd for $C_{23}H_{23}NO$: C, 83.85; H, 7.04; N, 4.25. Found: C, 84.04; H, 7.05; N, 4.29.

(2*S*,3*S*)-2-Hydroxymethyl-3-methyl-1-[(4-methylphenyl)sulfonyl]aziridine (6) Trifluoroacetic acid (75 ml) was added dropwise to a stirred solution of the trityl alcohol **5** (15 g, 45.5 mmol) in a mixed solvent of $CHCl_3$ (50 ml) and MeOH (25 ml) at −78 °C, then the mixture was allowed to warm to room temperature and stirring was continued for 3 h. The mixture was concentrated under reduced pressure to an oil, which was dissolved in 70 ml of $CHCl_3$. To the above stirred solution were added successively triethylamine (19 ml, 137 mmol) and *p*-toluenesulfonyl chloride (8.67 g, 45.5 mmol) at −40 °C. The mixture was allowed to warm to 0 °C and stirring was continued for 18 h. The reaction was quenched with 50 ml of a saturated $NaHCO_3$ solution with vigorous stirring. The mixture was extracted with EtOAc and the extract was washed successively with 5% HCl, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The usual work-up followed by flash chromatography over silica gel with *n*-hexane–EtOAc (2:1) gave a crystalline residue. Recrystallization from a mixed solvent of *n*-hexane–CH_2Cl_2–Et_2O (6:1:3) gave 6.31 g (60.9% yield) of the title compound **6** as colorless crystals. mp 67—69 °C. $[\alpha]_D^{26}$ + 5.06° (*c*=1.03, $CHCl_3$). IR ($CHCl_3$): 3500, 1592, 1314, 1145, 1085, 1028, 933, 564 cm^{-1}. ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.25 (3H, d, *J*=5.6 Hz), 1.74 (2H, m), 2.45 (3H, s), 2.97 (2H, m), 3.61 (1H, dd, *J*=11.5, 6.4 Hz), 3.76 (1H, dd, *J*=11.5, 4.6 Hz), 7.27—7.37 (2H, m), 7.81—7.85 (2H, m). *Anal.* Calcd for $C_{11}H_{15}NO_3S$: C, 54.75; H, 6.27; N, 5.80. Found: C, 54.56; H, 6.39; N, 5.79.

(2*S*,3*S*)-2-Hydroxymethyl-1-methanesulfonyl-3-methylaziridine (7) Trifluoroacetic acid (2 ml) was added dropwise to a stirred solution of the trityl alcohol **5** (988 mg, 3 mmol) in a mixed solvent of $CHCl_3$ (5 ml) and MeOH (2 ml) at 0 °C, then the mixture was allowed to warm to room temperature and stirred at this temperature for 3 h. The mixture was concentrated under reduced pressure to leave an oily residue. This was taken up in chloroform (5 ml) and toluene (5 ml), and the resulting solution was concentrated under reduced pressure. The residual oil was dissolved in 5 ml of $CHCl_3$. Diisopropylethylamine (2.08 ml, 12 mmol) was added at 0 °C, then methanesulfonyl chloride (0.523 ml, 3 mmol) was added dropwise with vigorous stirring. The mixture was stirred at 0 °C for 16 h, and the mixture was directly flash-chromatographed on a silica gel column. Elution with EtOAc gave 157 mg (32% yield) of the title compound **7** as a colorless oil. Kugelrohr distillation, 130 °C (1 mmHg). $[\alpha]_D^{28}$ +1.19° (*c*=0.673, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.35 (3H, doubletoid m), 2.06 (1H, m), 2.98 (2H, m), 3.08 (3H, s), 3.70 (1H, m), 3.86 (1H, m). LR-MS (FAB) *m/z*: 166 (MH^+), 148, 122, 86. HR-MS (FAB) *m/z* Calcd for $C_5H_{11}NO_3S$ (MH^+): 166.0537. Found: 166.0532.

(2*R*,3*S*)-2-Methoxycarbonyl-3-methyl-1-tritylaziridine (9) Thionyl chloride (6.1 ml, 84 mmol) was added dropwise to stirred dry MeOH (30 ml) at −78 °C and the mixture was stirred at 0 °C for 30 min. D-Allothreonine (5 g, 42 mmol) was added to the mixture at room temperature and the mixture was heated under reflux for 8 h. The mixture was concentrated under reduced pressure to give a semisolid, which was dissolved in 25 ml of *N*,*N*-dimethylformamide (DMF). To this solution, Et_3N (11.7 ml, 84 mmol) was added, followed by trityl chloride (11.7 g, 42 mmol) in 10 ml of DMF at 0 °C, and the mixture was stirred at room temperature for 18 h. A saturated NH_4Cl solution (30 ml) was added and the whole was extracted with EtOAc. The extract was washed successively with water, 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. Concentration under reduced pressure gave a crystalline residue, which was recrystallized from CH_2Cl_2–Et_2O (1:10) to give 11.36 g (72% yield) of methyl (2*R*,3*R*)-2-amino-3-hydroxy-*N*-tritylbutanoate as colorless crystals. mp 146 °C. $[\alpha]_D^{20}$ −16.6° (*c*=1.49, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.11 (3H, d, *J*=6.5 Hz), 3.23 (3H, s), 3.40 (1H, d, *J*=3.9 Hz), 3.99 (1H, m), 7.16—7.29 (10H, m), 7.48—7.52 (5H, m). *Anal.* Calcd for $C_{24}H_{25}NO_3$: C, 76.77; H, 6.71; N, 3.73. Found: C, 76.96; H, 6.68; N, 3.72. Sulfuryl chloride (1.6 ml, 20 mmol) in toluene (150 ml) was added to a stirred solution of 6 g (16 mmol) of methyl (2*R*,3*R*)-2-amino-3-hydroxy-*N*-tritylbutanoate in a mixture of 6.7 ml (48 mmol) of Et_3N and 270 ml of toluene at −78 °C during a period of 15 min, and the mixture was stirred for 18 h with warming to room temperature. The mixture was diluted with 200 ml of EtOAc, and the solution was washed successively with water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The mixture was concentrated under reduced pressure to an oil, which was flash chromatographed on a silica gel column. Elution with *n*-hexane–EtOAc (6:1) gave 4.56 g (80% yield) of the title compound **9** as a crystalline mass. Recrystallization from MeOH gave colorless crystals. mp 41 °C. $[\alpha]_D^{17}$ −38.3° (*c* = 0.987, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.60 (3H, d, *J*=6.1 Hz), 2.35 (1H, d, *J*=2.4 Hz), 2.98 (1H, ddd, *J*=12.3, 6.1, 2.4 Hz), 3.68 (3H, s), 7.17—7.28 (10H, m), 7.55—7.75 (5H, m). *Anal.* Calcd for $C_{24}H_{23}NO_2$: C, 80.64; H, 6.49; N, 3.92. Found: C, 80.99; H, 6.22; N, 3.49.

Methyl (2*R*,3*R*)-3-Hydroxy-2-(4-methylphenyl)sulfonamidobutanoate (11) Triethylamine (4.86 ml, 33.6 mmol), followed by *p*-toluenesulfonyl chloride (3.2 g, 16.8 mmol) in 10 ml of DMF, was added to a stirred solution of 2.85 g (16.8 mmol) of methyl (2*R*,3*R*)-2-amino-3-hydroxybutanoate hydrochloride in 15 ml of DMF at 0 °C, and the mixture was stirred at room temperature for 18 h. A saturated ammonium chloride solution (20 ml) was added and the mixture was extracted with EtOAc. The extract was washed successively with water, 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. Concentration under reduced pressure gave a crystalline residue, which was recrystallized from *n*-hexane–Et_2O (1:10) to give 3.125 g (65% yield) of the title compound **11** as colorless crystals. mp 100 °C. $[\alpha]_D^{20}$ −20.7° (*c*=0.987, $CHCl_3$). IR ($CHCl_3$): 3460, 1738, 1603 cm^{-1}. ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.18 (3H, d, *J*=6.4 Hz), 2.43 (3H, s), 3.54 (3H, s), 3.95 (1H, dd, *J*=9.0, 4.2 Hz), 4.08 (1H, m), 5.56 (1H, d, *J*=8.8 Hz), 7.29—7.33 (2H, m),

7.70—7.77 (2H, m). *Anal.* Calcd for $C_{12}H_{17}NO_5S$: C, 50.16; H, 5.96; N, 4.87. Found: C, 50.10; H, 5.99; N, 4.79.

(2*R*,3*S*)-2-Methoxycarbonyl-3-methyl-1-[(4-methylphenyl)sulfonyl]-aziridine (12) Diethyl azodicarboxylate (3.28 ml, 20.88 mmol) was added dropwise to a stirred mixture of the ester **11** (5 g, 17.4 mmol) and triphenylphosphine (5.48 g, 20.88 mmol) in 25 ml of THF at 0 °C, and the mixture was allowed to warm to room temperature then stirred at this temperature for 18 h. The mixture was concentrated under reduced pressure to an oil, which was flash-chromatographed on a silica gel column. Elution with *n*-hexane–EtOAc (3 : 1) gave 4.24 g (90% yield) of the title compound **12** as a colorless oil. $[\alpha]_D^{20}$ +15.6° (c=1.2, $CHCl_3$). IR ($CHCl_3$): 1741, 1603 cm^{-1}. ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.74 (3H, d, J=5.9 Hz), 2.44 (3H, s), 3.14 (1H, ddd, J=12.0, 6.1, 3.9 Hz), 3.35 (1H, d, J=3.9 Hz), 3.70 (3H, s), 7.31—7.35 (2H, m), 7.82—7.88 (2H, m). LR-MS (EI) m/z: 269 (M^+), 238, 210, 198, 155, 139, 114 (base peak), 91. HR-MS (EI) m/z Calcd for $C_{12}H_{15}NO_4S$: 269.0721. Found: 269.0706.

(2*R*)-2-(4-Methylphenyl)sulfonamido-1-butanol (13) DIBAL in *n*-hexane (5.1 ml, 4.72 mmol; 0.93 M solution) was added dropwise by syringe to a stirred solution of the ester **12** (318 mg, 1.18 mmol) in 2 ml of CH_2Cl_2 at −78 °C under argon and the mixture was stirred for 7 h at the same temperature. Then a saturated NH_4Cl solution (5 ml) was added dropwise with vigorous stirring at −78 °C. The inorganic salts were removed by filtration through Celite. The filtrate was extracted with EtOAc and the extract was washed with water and dried over $MgSO_4$. The usual work-up and flash chromatography over silica gel with *n*-hexane–EtOAc (2 : 1) gave 91 mg (31.8% yield) of (2*R*)-2-(4-methylphenyl)sulfonamido-1-butanol **13** and further elution gave 30 mg (11% yield) of (2*R*,3*S*)-3-methyl-1-[(4-methylphenyl)sulfonyl]-2-aziridinemethanol **22**. **13**: A colorless oil. $[\alpha]_D^{20}$ + 31.4° (c=0.803, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.75 (3H, t, J=7.4 Hz), 1.32—1.54 (2H, m), 2.18 (1H, br s), 2.43 (3H, s), 3.17 (1H, m), 3.50 (1H, dd, J=11.2, 5.2 Hz), 3.62 (1H, dd, J=11.2, 4.0 Hz), 4.95 (1H, d, J=7.8 Hz), 7.28—7.33 (2H, m), 7.76—7.80 (2H, m). *Anal.* Calcd for $C_{11}H_{17}NO_3S$: C, 54.30; H, 7.04; N, 5.76. Found: C, 54.06; H, 6.90; N, 6.02.

Methyl (2*R*,3*R*)-3-Hydroxy-2-(4-methylphenyl)sulfonamido-2,3-*N*,*O*-isopropylidenebutanoate (14) Boron trifluoride etherate (0.064 ml, 0.696 mmol) was added to a stirred solution of **11** (1 g, 3.48 mmol) in a mixture of CH_2Cl_2 (5 ml), 2,2-dimethoxypropane (8.6 ml, 69.6 mmol), and acetone (1.28 ml, 17.4 mmol) at 0 °C, and the mixture was stirred for 18 h with warming to room temperature. The mixture was poured into a cold saturated $NaHCO_3$ solution (5 ml) and stirring was continued for 1 h with warming to room temperature. The mixture was extracted with Et_2O and the extract was washed with water and dried over $MgSO_4$. The usual work-up and flash chromatography over silica gel with *n*-hexane–EtOAc (4 : 1) gave a crystalline residue. Recrystallization from a mixed solvent of CH_2Cl_2–Et_2O (1 : 10) gave 699 mg (61% yield) of the title compound **14** as colorless crystals. mp 114 °C. $[\alpha]_D^{20}$ + 56.7° (c=0.815, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.19 (3H, d, J=6.0 Hz), 1.64 (3H, s), 1.80 (3H, s), 2.42 (3H, s), 3.52 (3H, s), 4.26—4.42 (2H, m), 7.27—7.31 (2H, m), 7.71—7.76 (2H, m). *Anal.* Calcd for $C_{15}H_{21}NO_5S$: C, 55.03; H, 6.47; N, 4.28. Found: C, 54.74; H, 6.50; N, 4.26.

(2*S*,3*R*)-3-Hydroxy-2-(4-methylphenyl)sulfonamido-2,3-*N*,*O*-isopropylidene-1-butanol (15) DIBAL in *n*-hexane (4.9 ml, 4.58 mmol; 0.93 M solution) was added dropwise to a stirred solution of the ester **14** (600 mg, 1.83 mmol) in 2 ml of CH_2Cl_2 at −78 °C under argon. The mixture was allowed to warm to 0 °C, and stirring was continued for 1 h. The mixture was recooled to −78 °C, and a saturated NH_4Cl solution (10 ml) was added dropwise with vigorous stirring. The inorganic salts were removed by filtration through Celite. The filtrate was extracted with EtOAc and the extract was washed with water and dried over $MgSO_4$. The usual work-up and flash chromatography over silica gel with *n*-hexane–EtOAc (3 : 1) gave 32 mg (5.9% yield) of (2*S*,3*R*)-2-[(4-methylphenyl)sulfonyl]amino-1,3-(isopropylidenedioxy)butane [a colorless oil; $[\alpha]_D^{20}$ + 28.0° (c=0.714, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.06 (3H, d, J=6.0 Hz), 1.33 (3H, s), 1.38 (3H, s), 2.43 (3H, s), 2.93—3.10 (1H, m), 3.45 (1H, m), 3.57—3.70 (2H, m), 5.03 (1H, d, J=8.8 Hz), 7.30—7.34 (2H, m), 7.76—7.80 (2H, m); LR-MS (EI) m/z: 300 (MH^+), 284, 197 (base peak), 155, 133, 91; HR-MS (EI) m/z Calcd for $C_{14}H_{22}NO_4S$ (MH^+): 300.1269; Found: 300.1256] as a by-product and further elution gave 432 mg (79% yield) of the title compound **15**. **15**: Colorless crystals from Et_2O-*n*-hexane (1 : 5). mp 90 °C. $[\alpha]_D^{20}$ +12.5° (c=0.865, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.27 (3H, d, J=6.6 Hz), 1.53 (3H, s), 1.71 (3H, s), 2.44 (3H, s), 2.72 (1H, m), 3.53—3.76 (3H, m), 4.00 (1H, m), 7.29—7.34 (2H, m), 7.76—7.81 (2H, m). *Anal.* Calcd for $C_{14}H_{21}NO_4S$: C, 56.17; H, 7.07; N, 4.68. Found: C, 55.87; H, 7.05; N, 4.54.

(2*S*,3*R*)-1-Benzyloxy-3-hydroxy-2-(4-methylphenyl)sulfonamido-2,3-*N*,*O*-isopropylidenebutane (16) The alcohol **15** (250 mg, 0.835 mmol) in 2 ml of DMF, followed by benzyl bromide (0.2 ml, 1.67 mmol), was added by syringe to a stirred suspension of NaH (80 mg, 3.34 mmol) in 2 ml of DMF at 0 °C under argon. The mixture was stirred for 3 h with warming to room temperature. It was then poured into ice-water (10 ml) and stirred for 1 h at this temperature. The mixture was extracted with Et_2O and the extract was washed with water and dried over $MgSO_4$. The usual work-up and flash chromatography over silica gel with *n*-hexane–EtOAc (5 : 1) gave a crystalline residue. Recrystallization from a mixed solvent of *n*-hexane–Et_2O (3 : 1) gave 305 mg (94% yield) of **16** as colorless crystals. mp 87 °C. $[\alpha]_D^{20}$ +80.9° (c=0.918, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.29 (3H, d, J=6.4 Hz), 1.50 (3H, s), 1.64 (3H, s), 2.42 (3H, s), 3.57—3.69 (2H, m), 3.73—3.81 (1H, m), 4.01 (1H, m), 4.46 (2H, s), 7.25—7.41 (7H, m), 7.72—7.78 (2H, m). *Anal.* Calcd for $C_{21}H_{27}NO_4S$: C, 64.76; H, 6.99; N, 3.60. Found: C, 64.51; H, 6.91; N, 3.51.

(3*S*,2*R*)-4-Benzyloxy-3-(4-methylphenyl)sulfonamido-2-butanol (17) A solution of the acetonide **16** (270 mg, 0.69 mmol) in a mixture of 1 N HCl (5 ml) and MeOH (15 ml) was stirred for 5 h at room temperature. Sodium bicarbonate (500 mg) was added to the mixture at 0 °C with stirring. The whole was concentrated under reduced pressure to an oily residue, which was extracted with EtOAc. The extract was washed with water and dried over $MgSO_4$. The usual work-up and flash chromatography over silica gel with *n*-hexane–EtOAc (3 : 1) gave 214 mg (89% yield) of **17** as a colorless oil. $[\alpha]_D^{20}$ +23.7° (c=0.6811, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.16 (3H, d, J=6.8 Hz), 2.42 (3H, s), 2.51 (1H, m), 3.18—3.28 (1H, m), 3.34—3.41 (1H, m), 3.64—3.78 (2H, m), 4.36 (2H, s), 5.29 (1H, d, J=7.8 Hz), 7.19—7.40 (7H, m), 7.70—7.74 (2H, m). LR-MS (EI) m/z: 349 (M^+), 304, 228, 197, 194, 155, 91 (base peak). HR-MS (EI) m/z Calcd for $C_{18}H_{23}NO_4S$ (M^+): 349.1348. Found: 349.1349.

(2*R*,3*S*)-2-Benzyloxymethyl-3-methyl-1-[(4-methylphenyl)sulfonyl]-aziridine (18) Triphenylphosphine (222 mg, 0.846 mmol), followed by diethyl azodicarboxylate (0.133 ml, 0.846 mmol), was added to a stirred solution of the protected amino alcohol **17** (197 mg, 0.56 mmol) in 2 ml of THF at 0 °C, and the mixture was allowed to warm to room temperature then stirred at this temperature for 18 h. It was concentrated under reduced pressure to afford an oil, which was flash-chromatographed on a silica gel column. Elution with *n*-hexane–EtOAc (5 : 1) gave 109 mg (59% yield) of the title compound **18** as a colorless oil. $[\alpha]_D^{20}$ −3.5° (c=0.81, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$) δ: 1.60 (3H, d, J=5.8 Hz), 2.41 (3H, s), 2.80 (1H, m), 3.01 (1H, ddd, J=6.1, 4.8, 4.8 Hz), 3.53 (1H, dd, J=11.1, 6.1 Hz), 3.66 (1H, dd, J=11.1, 4.9 Hz), 4.41 (2H, s), 7.16—7.36 (7H, m), 7.82—7.87 (2H, m). LR-MS (EI) m/z: 331 (M^+), 260, 210, 176, 155, 91 (base peak). HR-MS (EI) m/z Calcd for $C_{18}H_{21}NO_3S$ (M^+): 331.1242. Found: 331.1244.

(2*S*,3*R*)-2-(4-Methylphenyl)sulfonamido-1,3-butanediol (19) DIBAL in *n*-hexane (292 ml, 271 mmol; 0.93 M solution) was added dropwise to a stirred solution of methyl (*R*)-*N*-[(4-methylphenyl)sulfonyl]allothreoninate **11** (13 g, 45.2 mmol) in 100 ml of CH_2Cl_2 at −78 °C under argon. The mixture was allowed to warm to room temperature and stirring was continued for 18 h. The mixture was recooled to −78 °C, and a saturated NH_4Cl solution (50 ml) was added dropwise with vigorous stirring. The mixture was concentrated to dryness under reduced pressure at 60 °C. The residue was mixed with an approximately equal volume of silica gel and the resultant powder was packed into a column. Elution with EtOAc–MeOH (85 : 15) gave a mixture of products, which was purified by flash chromatography over silica gel with *n*-hexane–EtOAc (1 : 3) to yield a crystalline mass. Recrystallization from CH_2Cl_2–Et_2O (1 : 9) gave 6.81 g (58.2% yield) of the title compound **19** as colorless crystals. mp 95—96 °C. $[\alpha]_D^{20}$ −0.16° (c=1.26, $CHCl_3$). IR ($CHCl_3$): 3500, 3370, 1600, 1400, 1323, 1153, 1075, 848 cm^{-1}. ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.19 (3H, d, J=6.3 Hz), 2.43 (3H, s), 2.80 (2H, br s), 3.09 (1H, m), 3.51 (1H, dd, J=11.7, 3.4 Hz), 3.83—3.94 (2H, m), 5.86 (1H, d, J=8.1 Hz), 7.29—7.33 (2H, m), 7.75—7.80 (2H, m). *Anal.* Calcd for $C_{11}H_{17}NO_4S$: C, 50.95; H, 6.61; N, 5.40. Found: C, 50.68; H, 6.62; N. 5.26.

(2*R*,3*S*)-4-*tert*-Butyldimethylsiloxy-2-(4-methylphenyl)sulfonamido-2-butanol (20) *tert*-Butyldimethylsilyl chloride (2.55 g, 16.94 mmol) in 20 ml of DMF was added dropwise to a stirred mixture of the alcohol

19 (4 g, 15.4 mmol), imidazole (2.31 g, 33.88 mmol), and 4-dimethylaminopyridine (0.188 g, 1.54 mmol) in 10 ml of DMF at 0 °C, and the mixture was stirred for 1 h with warming to room temperature. The reaction was quenched with saturated $NaHCO_3$ (5 ml) at 0 °C and stirring was continued for 1 h with warming to room temperature. The mixture was extracted with EtOAc and the extract was washed successively with 5% HCl, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The usual work-up followed by flash chromatography over silica gel with *n*-hexane–EtOAc (2 : 1) gave 4.80 g (83.1% yield) of the title compound **20** as a colorless oil. $[\alpha]_D^{20}$ +16.9° (c=0.984, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.00 (3H, s), 0.02 (3H, s), 0.85 (9H, s), 1.19 (3H, d, J=6.5 Hz), 2.43 (3H, s), 2.66 (1H, d, J=7.6 Hz), 3.13 (1H, m), 3.54 (1H, dd, J=10.5, 3.8 Hz), 3.70 (1H, m), 3.83 (1H, dd, J=10.5, 3.4 Hz), 5.23 (1H, d, J=8.0 Hz), 7.29—7.32 (2H, m), 7.75—7.78 (2H, m). *Anal.* Calcd for $C_{17}H_{31}NO_4SSi$: C, 54.66; H, 8.36; N, 3.75. Found: C, 54.64; H, 8.52; N, 3.75.

(2*R*,3*S*)-2-(*tert*-Butyldimethylsiloxy)methyl-3-methyl-1-[(4-methylphenyl)sulfonyl]aziridine (21) Diethyl azodicarboxylate (0.094 ml, 0.6 mmol) was added dropwise by syringe to a stirred mixture of the alcohol **20** (150 mg, 0.4 mmol) and triphenylphosphine (157 mg, 0.6 mmol) in 25 ml of THF at 0 °C, then the mixture was allowed to warm to room temperature and stirred at this temperature for 18 h. It was concentrated under reduced pressure to an oil, which was flash chromatographed on a silica gel column. Elution with *n*-hexane–EtOAc (4 : 1) gave 124 mg (87% yield) of the title compound **21** as a colorless oil. $[\alpha]_D^{20}$ −2.77° (c=1.01, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: −0.06 (3H, s), −0.04 (3H, s), 0.82 (9H, s), 1.62 (3H, d, J=6.0 Hz), 2.42 (3H, s), 2.79 (1H, m), 2.92 (1H, dd, J=9.7, 4.9 Hz), 3.67 (1H, dd, J=11.4, 5.3 Hz), 3.73 (1H, dd, J=11.4, 4.9 Hz), 7.28—7.31 (2H, m), 7.83—7.85 (2H, m). *Anal.* Calcd for $C_{17}H_{29}NO_3SSi$: C, 57.43; H, 8.22; N, 3.94. Found: C, 57.44; H, 8.07; N, 3.99.

(2*R*,3*S*)-3-Methyl-1-(4-methylphenyl)sulfonyl-2-aziridinemethanol (22) Tetrabutylammonium fluoride in THF (6.32 ml, 6.32 mmol; 1.0 M solution) was added by syringe to a stirred solution of **21** (2.14 g, 6.02 mmol) in 7 ml of THF at 0 °C, and the mixture was stirred for 20 min at 0 °C, then poured into ice-water and extracted with EtOAc. The extract was successively washed with 5% citric acid, saturated brine, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue which was purified by flash chromatography over silica gel with *n*-hexane–EtOAc (2 : 1) to yield 1.37 g (95% yield) of the title compound **22** as a colorless oil. $[\alpha]_D^{20}$ −22.0° (c=0.723, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.44 (3H, d, J=5.4 Hz), 2.38 (3H, dd, J=8.2, 5.7 Hz), 2.44 (3H, s), 2.97 (2H, m), 3.78 (1H, m), 4.00 (1H, ddd, J=13.1, 8.2, 2.8 Hz), 7.31—7.35 (2H, m), 7.82—7.86 (2H, m). *Anal.* Calcd for $C_{11}H_{15}NO_3S$: C, 54.75; H, 6.27; N, 5.80. Found: C, 54.09; H, 6.22; N, 5.71.

(1*S*,2*S*)-3-*tert*-Butyldimethylsiloxy-2-(4-methylphenyl)sulfonamido-1-phenyl-1-propanol (25) *p*-Toluenesulfonyl chloride (29.8 g, 156.5 mmol) was added in portions to a stirred mixture of (1*S*,2*S*)-(+)-2-amino-1-phenyl-1,3-propanediol **23** (25 g, 149.5 mmol) and Et_3N (21.8 ml, 156.5 mmol) in 300 ml of DMF at 0 °C, and the mixture was stirred at room temperature for 18 h. Then imidazole (20.4 g, 299 mmol) was added, followed by *tert*-butyldimethylsilyl chloride (22.5 g, 149.5 mmol) in DMF (100 ml) at 0 °C, and the mixture was stirred with warming to room temperature for 18 h. It was then cooled to 0 °C, and a saturated NH_4Cl solution (100 ml) was added dropwise with vigorous stirring. The whole was extracted with EtOAc and the extract was washed successively with 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. Concentration under reduced pressure gave a crystalline residue, which was recrystallized from CH_2Cl_2–*n*-hexane (1 : 1) to give 44.1 g (68% yield) of the title compound **25** as colorless crystals. mp 135 °C. $[\alpha]_D^{20}$ +49.4° (c=0.782, $CHCl_3$). ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 0.052 (3H, s), 0.060 (3H, s), 0.91 (9H, s), 2.36 (3H, s), 3.32 (1H, m), 3.42 (1H, d, J=1.6 Hz), 3.65 (1H, dd, J=10.4, 2.8 Hz), 3.70 (1H, dd, J=10.4, 4.2 Hz), 4.92 (1H, dd, J=4.2, 2.0 Hz), 5.16 (1H, d, J=8.4 Hz), 7.06—7.09 (2H, m), 7.12—7.20 (5H, m), 7.40—7.45 (2H, m). *Anal.* Calcd for $C_{22}H_{33}NO_4SSi$: C, 60.65; H, 7.64; N, 3.22. Found: C, 60.47; H, 7.67; N, 3.18.

(2*R*,3*R*)-2-(*tert*-Butyldimethylsiloxy)methyl-3-phenyl-1-[(4-methylphenyl)sulfonyl]aziridine (26) Triphenylphosphine (21.0 g, 80 mmol), followed by diethyl azodicarboxylate (12.6 ml, 80 mmol), was added to a stirred solution of the protected amino alcohol **25** (34.9 g, 80 mmol) in 150 ml of THF at 0 °C, and the mixture was allowed to warm to room temperature and stirred at this temperature for 3 h. The mixture was concentrated under reduced pressure to an oil, which was flash-chromatographed on a silica gel column. Elution with *n*-hexane–EtOAc (6 : 1) gave 26.6 g (80% yield) of the title compound **26** as a colorless oil. $[\alpha]_D^{20}$ −63.9° (c=1.09, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: −0.21 (3H, s), −0.18 (3H, s), 0.75 (9H, s), 2.44 (3H, s), 3.21—3.32 (2H, m), 3.50 (1H, ddd, J=10.7, 6.7, 5.5 Hz), 4.02 (1H, d, J=6.7 Hz), 7.21—7.30 (5H, m), 7.32—7.35 (2H, m), 7.88—7.92 (2H, m). *Anal.* Calcd for $C_{22}H_{31}NO_3SSi$: C, 63.27; H, 7.48; N, 3.35. Found: C, 63.16; H, 7.52; N, 3.18.

(2*R*,3*R*)-1-(4-Methylphenyl)sulfonyl-3-phenyl-2-aziridinemethanol (27) Tetrabutylammonium fluoride in THF (44 ml, 44 mmol; 1.0 M solution) was added by syringe to a stirred solution of **26** (16.7 g, 40 mmol) in 50 ml of THF at 0 °C, and the mixture was stirred for 30 min at 0 °C, poured into ice-water and extracted with EtOAc. The extract was successively washed with 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue, which was purified by flash chromatography over silica gel with *n*-hexane–EtOAc (2 : 1) to yield 10.9 g (90% yield) of the title compound **27**. **27**: Colorless crystals from *n*-hexane–Et_2O (1 : 5). mp 88 °C. $[\alpha]_D^{20}$ −126.9° (c=1.32, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.49 (1H, m), 2.44 (3H, s), 3.30 (1H, m), 3.38 (1H, dd, J=6.9, 5.0 Hz), 3.48 (1H, m), 4.04 (1H, d, J=6.9 Hz), 7.20—7.31 (5H, m), 7.34—7.37 (2H, m), 7.88—7.92 (2H, m). *Anal.* Calcd for $C_{16}H_{17}NO_3S$: C, 63.35; H, 5.65; N, 4.62. Found: C, 63.60; H, 5.47; N, 4.52.

(2*R*,3*S*)-1-(4-Methylphenyl)sulfonyl-3-phenyl-2-aziridinemethanol (30) from 29 A mixture of the dihydroxy azide **29**[21,22] (1.7 g, 8.8 mmol), triphenylphosphine (2.3 g, 8.8 mmol), and toluene (20 ml) was heated under reflux for 2 h. After cooling, triethylamine (3 ml, 22 mmol) and *p*-toluenesulfonyl chloride (1.68 g, 8.8 mmol) were added to the above mixture at 0 °C, and the whole was stirred at room temperature for 4 h. It was cooled to 0 °C, and a saturated $NaHCO_3$ solution (5 ml) was added with vigorous stirring. This mixture was extracted with Et_2O and the extract was washed successively with 5% citric acid, water, 5% $NaHCO_3$, and water and dried over $MgSO_4$. The usual work-up followed by flash chromatography over silica gel with *n*-hexane–EtOAc (4 : 1) gave 700 mg (26% yield) of the title compound **30** as a colorless oil. $[\alpha]_D^{15}$ +49.0° (c=0.7, $CHCl_3$). ^{1}H-NMR ($CDCl_3$) δ: 2.40 (3H, s), 3.15 (1H, dd, J=9.8, 4.9 Hz), 3.19 (1H, ddd, J=8.4, 4.4, 3.1 Hz), 4.02 (1H, d, J=4.4 Hz), 4.19 (1H, ddd, J=13.3, 8.4, 4.9 Hz), 4.32 (1H, ddd, J=13.3, 9.8, 3.2 Hz), 7.13—7.16 (2H, m), 7.26—7.29 (5H, m), 7.81—7.85 (2H, m). LR-MS (FAB) m/z: 304 (MH^+), 274 (base peak), 155, 148, 118, 91. HR-MS (FAB) m/z Calcd for $C_{16}H_{18}NO_3S$ (MH^+): 304.1007. Found: 304.1009.

(2*R*,3*S*)-1-(4-Methylphenyl)sulfonyl-3-phenyl-2-aziridinemethanol (30) from 34 Tetrabutylammonium fluoride (3.1 ml, 3.1 mmol; 1 M solution in THF) was added by syringe to a stirred solution of **34** (1.3 g, 3.1 mmol) in 10 ml of THF at −78 °C, and the mixture was allowed to warm to 0 °C then stirred at this temperature for an additional 1 h. The mixture was poured into ice-water and extracted with Et_2O. The extract was washed successively with 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue which was purified by flash chromatography over silica gel with *n*-hexane–EtOAc (4 : 1) to give 890 mg (94% yield) of the title compound **30** as a colorless oil. $[\alpha]_D^{15}$ +48.4° (c=1.50, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 2.40 (3H, s), 3.15 (1H, dd, J=9.8, 4.9 Hz), 3.19 (1H, ddd, J=8.4, 4.4, 3.1 Hz), 4.02 (1H, d, J=4.4 Hz), 4.19 (1H, ddd, J=13.3, 8.4, 4.9 Hz), 4.32 (1H, ddd, J=13.3, 9.8, 3.2 Hz), 7.13—7.16 (2H, m), 7.26—7.29 (5H, m), 7.81—7.85 (2H, m). LR-MS (FAB) m/z: 304 (MH^+), 274 (base peak), 155, 148, 118, 91. HR-MS (FAB) m/z Calcd for $C_{16}H_{18}NO_3S$ (MH^+): 304.1007. Found: 304.1008.

(2*R*,3*R*)-2,3-Epoxy-3-phenyl-1-propanol *tert*-Butyldimethylsilyl Ether (31) By use of a procedure identical with that described for the preparation of **20**, the epoxy alcohol **28**[14b] (1.5 g, 10 mmol, 98% ee) was converted into the silyl ether **31** (2.49 g, 94% yield) as a colorless oil. Kugelrohr distillation, 140 °C (1 mmHg). $[\alpha]_D^{20}$ +30.3° (c=1.12, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.104 (3H, s), 0.113 (3H, s), 0.92 (9H, s), 3.14 (1H, m), 3.80 (1H, d, J=2.0 Hz), 3.82 (1H, dd, J=12.0, 4.3 Hz), 3.96 (1H, dd, J=12.0, 3.1 Hz), 7.25—7.37 (5H, m). *Anal.* Calcd for $C_{15}H_{24}O_2Si$: C, 68.13; H, 9.15. Found: C, 68.19; H, 9.23.

(2*S*,3*S*)-3-Azido-1-*tert*-butyldimethylsiloxy-2-hydroxy-3-phenylpropane (32) and (2*S*,3*R*)-2-Azido-1-*tert*-butyldimethylsiloxy-3-hydroxy-3-phenylpropane (33) Sodium azide (1.98 g, 30.5 mmol) and ammonium chloride (647 mg, 12.2 mmol) were added to a stirred solution of the epoxy silyl ether **31** (1.6 g, 6.1 mmol) in 29 ml of a 1 : 8 mixture of water and ethylene glycol monomethyl ether, and the mixture was

heated at 85 °C for 5 h under stirring. The mixture was concentrated under reduced pressure, and the residual semisolid was extracted with Et_2O. The extract was washed with brine and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue which was flash-chromatographed over silica gel. Elution with *n*-hexane–EtOAc (10 : 1) gave 1.595 g (85% yield) of **32** as a colorless oil and further elution yielded 250 mg (13% yield) of **33** as a colorless oil. **32**: $[\alpha]_D^{20}$ +112° (c = 0.99, $CHCl_3$). Kugelrohr distillation, 150 °C (1 mmHg). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.08 (3H, s), 0.09 (3H, s), 0.91 (9H, s), 2.46 (1H, d, J = 4.9 Hz), 3.67 (1H, dd, J = 10.1, 4.1 Hz), 3.73 (1H, dd, J = 10.1, 5.5 Hz), 3.85 (1H, m), 4.59 (1H, d, J = 7.1 Hz), 7.25—7.44 (5H, m). *Anal.* Calcd for $C_{15}H_{25}N_3O_2Si$: C, 58.60; H, 8.20; N, 13.67. Found: C, 58.81; H, 8.08; N, 13.55. **33**: $[\alpha]_D^{20}$ +124° (c = 1.29, $CHCl_3$). Kugelrohr distillation, 150 °C (1 mmHg). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: −0.34 (3H, s), −0.04 (3H, s), 0.78 (9H, s), 1.92 (1H, dd, J = 8.3, 4.2 Hz), 3.61 (1H, m), 3.80 (2H, m), 4.64 (1H, d, J = 7.2 Hz), 7.26—7.40 (5H, m). *Anal.* Calcd for $C_{15}H_{25}N_3O_2Si$: C, 58.60; H, 8.20; N, 13.67. Found: C, 58.53; H, 8.09; N, 13.61.

(2*R*,3*S*)-2-(*tert*-Butyldimethylsiloxy)methyl-1-(4-methylphenyl)sulfonyl-3-phenylaziridine (34) A mixture of the azide **32** (1.59 g, 5.2 mmol), triphenylphosphine (1.5 g, 5.72 mmol), and toluene (20 ml) was heated under reflux for 2 h. After cooling, triethylamine (5 ml, 36 mmol) and *p*-toluenesulfonyl chloride (1.49 g, 5.8 mmol) were added to the above mixture at 0 °C, and the whole was stirred at room temperature for 3 h. It was cooled to 0 °C, and a saturated $NaHCO_3$ solution (5 ml) was added with vigorous stirring. This mixture was extracted with Et_2O and the extract was washed successively with 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The usual work-up followed by flash chromatography over silica gel with *n*-hexane–EtOAc (5 : 1) gave 2.0 g (92% yield) of the title compound **34** as a colorless oil.

By a procedure identical with that described for the preparation of **34** from **32**, 300 mg (1.0 mmol) of the azide **33** was converted into the title compound **34** (400 mg, 98% yield) as a colorless oil. **34**: $[\alpha]_D^{20}$ +35.7° (c = 1.29, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.095 (6H, s), 0.90 (9H, s), 2.39 (2H, s), 3.10 (1H, ddd, J = 6.9, 6.8, 4.5 Hz), 3.88 (1H, d, J = 4.3 Hz), 4.14 (1H, dd, J = 11.3, 7.0 Hz), 4.35 (1H, dd, J = 11.3, 5.0 Hz), 7.10—7.20 (2H, m), 7.20—7.30 (5H, m), 7.80—7.84 (2H, m). LR-MS (FAB) m/z: 418 (MH^+), 388, 360, 330, 262, 228, 204, 177, 149, 139, 91, 73 (base peak). HR-MS (FAB) m/z Calcd for $C_{22}H_{32}NO_3SSi$ (MH^+): 418.1872. Found: 418.1866.

(2*S*,3*R*)-4-Benzyloxy-1-*tert*-butyldimethylsilyloxy-2,3-epoxybutane (36) By use of a procedure identical with that described for the preparation of **20**, the epoxy alcohol **35**[23] (388 mg, 2 mmol, 86% ee) was converted into the silyl ether **36** (566 mg, 92% yield) as a colorless oil. Kugelrohr distillation, 150 °C (1 mmHg). $[\alpha]_D^{26}$ −4.26° (c = 0.892, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.06 (3H, s), 0.07 (3H, s), 0.89 (9H, s), 3.14 (1H, ddd, J = 5.8, 4.5, 4.5 Hz), 3.24 (1H, ddd, J = 6.4, 4.0, 4.0 Hz), 3.56 (1H, dd, J = 11.3, 6.4 Hz), 3.70 (1H, dd, J = 11.8, 5.8 Hz), 3.72 (1H, dd, J = 11.4, 3.9 Hz), 3.77 (1H, dd, J = 11.8, 4.5 Hz), 4.53 (1H, d, J = 11.8 Hz), 4.63 (1H, d, J = 11.8 Hz), 7.26—7.36 (5H, m). *Anal.* Calcd for $C_{17}H_{20}O_3Si$: C, 66.19; H, 9.15. Found: C, 65.93; H, 9.27.

(2*R*,3*S*)-3-Azido-4-benzyloxy-4-*tert*-butyldimethylsiloxy-2-hydroxybutane (37) and (2*R*,3*S*)-2-Azido-4-benzyloxy-1-*tert*-butyldimethylsiloxy-3-hydroxybutane (38) Sodium azide (162.5 mg, 2.5 mmol), followed by ammonium chloride (5.3 mg, 1 mmol), was added to a stirred solution of the epoxy silyl ether **36** (154 mg, 0.5 mmol) in 2 ml of a 1 : 8 mixture of water and ethylene glycol monomethyl ether, and the mixture was heated under reflux for 3 h. It was concentrated under reduced pressure, and the residual semisolid was extracted with $CHCl_3$. The extract was washed with brine and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue, which was flash-chromatographed over silica gel. Elution with *n*-hexane–EtOAc (7 : 1) gave 61 mg (34.7% yield) of **37** and further elution yielded 63.7 mg (36.2% yield) of **38**. **37**: A colorless oil. Kugelrohr distillation, 155 °C (1 mmHg). $[\alpha]_D^{26}$ +22.6° (c = 0.630, $CHCl_3$). IR ($CHCl_3$): 2100 cm^{-1} (N_3). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.06 (3H, s), 0.07 (3H, s), 0.89 (9H, s), 2.46 (1H, d, J = 5.1 Hz), 3.58—3.83 (6H, m), 4.55—4.59 (2H, m), 7.26—7.37 (5H, m). *Anal.* Calcd for $C_{17}H_{29}N_3O_3Si$: C, 58.09; H, 8.32; N, 11.95. Found: C, 58.14; H, 8.25; N, 11.43. **38**: A colorless oil. Kugelrohr distillation, 149 °C (1 mmHg). $[\alpha]_D^{26}$ −25.4° (c = 0.514, $CHCl_3$). IR ($CHCl_3$): 2100 cm^{-1} (N_3). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.09 (6H, s), 0.90 (9H, s), 2.56 (1H, br s), 3.49—3.54 (1H, m), 3.54—3.56 (2H, m), 3.85 (1H, dd, J = 10.6, 6.2 Hz), 3.92 (1H, dd, J = 10.6, 4.5 Hz), 3.95 (1H, m), 4.56 (2H, s), 7.25—7.39 (5H, m). *Anal.* Calcd for $C_{17}H_{29}N_3O_3Si$: C, 58.09; H, 8.32; N, 11.95. Found: C, 58.36; H, 8.37; N, 11.80.

(2*R*,3*S*)-3-Azido-4-benzyloxy-1,2-diacetoxybutane (39) Tetrabutylammonium fluoride in THF (0.090 ml, 0.090 mmol; 1 M solution) was added by syringe to a stirred solution of the azide alcohol **37** (30 mg, 0.085 mmol) in 1 ml of THF, and the mixture was stirred for 30 min at room temperature. Then 0.2 ml of acetic anhydride, 0.4 ml of pyridine, and 20 mg of 4-dimetylaminopyridine were added at 0 °C, and the whole was stirred for 1 h at room temperature. The reaction was quenched with saturated $NaHCO_3$ (5 ml) at 0 °C and stirring was continued for 1 h with warming to room temperature. The mixture was extracted with EtOAc and the extract was washed successively with 5% HCl, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The extract was concentrated under reduced pressure to an oil, which was flash-chromatographed on a silica gel column. Elution with *n*-hexane–EtOAc (3 : 1) gave 10.7 mg (39% yield) of the title compound **39** as a colorless oil. $[\alpha]_D^{20}$ +9.73° (c = 0.781, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 2.05 (3H, s), 2.07 (3H, s), 3.64 (2H, m), 3.75 (1H, ddd, J = 6.5, 4.5, 4.5 Hz), 4.13 (1H, dd, J = 11.9, 6.5 Hz), 4.32 (1H, dd, J = 11.9, 4.5 Hz), 4.55 (2H, s), 5.25 (1H, ddd, J = 6.5, 4.5, 4.5 Hz), 7.28—7.39 (5H, m). LR-MS (FAB) m/z: 322 (MH^+), 294, 149, 91 (base peak), 43. HR-MS (FAB) m/z Calcd for $C_{15}H_{20}N_3O_5$ (MH^+): 322.1403. Found: 322.1407.

(2*R*,3*S*)-2-Azido-4-benzyloxy-1,3-diacetoxybutane (40) By a procedure identical with that described for the synthesis of **39** from **37**, 25 mg (0.071 mmol) of **38** was converted into 25.6 mg (93% yield) of the title compound **40** as a colorless oil. $[\alpha]_D^{20}$ −9.31° (c = 0.816, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 2.09 (3H, s), 2.10 (3H, s), 3.59 (1H, dd, J = 10.2, 5.1 Hz), 3.64 (1H, dd, J = 10.2, 5.7 Hz), 3.98 (1H, ddd, J = 7.5, 4.4, 4.4 Hz), 4.13 (1H, dd, J = 11.6, 7.5 Hz), 4.28 (1H, dd, J = 11.6, 4.4 Hz), 4.52 (1H, d, J = 12.0 Hz), 4.57 (1H, d, J = 12.0 Hz), 5.14 (1H, m), 7.28—7.39 (5H, m). LR-MS (FAB) m/z: 322 (MH^+), 294, 214, 192, 149, 91 (base peak), 43. HR-MS (FAB) m/z Calcd for $C_{15}H_{20}N_3O_5$ (MH^+): 322.1403. Found: 322.1411.

(2*S*,3*R*)-3-(Benzyloxy)methyl-2-(*tert*-butyldimethylsiloxy)methyl-1-[(4-methylphenyl)sulfonyl]aziridine (41) A mixture of triphenylphosphine (86 mg, 0.327 mmol) and the azides **37** and **38** (1 : 1 mixture, 104.5 mg, 0.3 mmol) in 3 ml of THF was heated under reflux for 4 h, then allowed to cool. Triethylamine (0.062 ml, 0.446 mmol) and *p*-toluenesulfonyl chloride (85 mg, 0.446 mmol) were added to the above mixture at 0 °C, and the mixture was stirred at room temperature for 18 h. It was then cooled to 0 °C, and a saturated $NaHCO_3$ solution (10 ml) was added with vigorous stirring. The mixture was extracted with Et_2O and the extract was washed successively with 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The usual work-up followed by flash chromatography over silica gel with *n*-hexane–EtOAc (7 : 1) gave 62.4 mg (45.5% yield) of the title compound **41** as a colorless oil. $[\alpha]_D^{26}$ +2.6° (c = 0.539, $CHCl_3$). ^{1}H-NMR (270 MHz, $CDCl_3$) δ: −0.04 (3H, s), −0.03 (3H, s), 0.81 (9H, s), 2.41 (3H, s), 3.02 (1H, m), 3.13 (1H, m), 3.55 (1H, dd, J = 11.3, 6.3 Hz), 3.61 (1H, dd, J = 11.3, 4.9 Hz), 3.66 (2H, m), 4.42 (1H, d, J = 12.0 Hz), 4.48 (1H, d, J = 12.0 Hz), 7.20—7.24 (2H, m), 7.25—7.35 (5H, m), 7.82—7.86 (2H, m). LR-MS (EI) m/z: 461 (M^+), 448, 404, 374, 298, 270, 228, 210, 200, 149, 143, 91 (base peak). HR-MS (EI) m/z Calcd for $C_{24}H_{35}NO_4SSi$ (M^+): 461.2056. Found: 461.2060.

(2*S*,3*R*)-3-(Benzyloxy)methyl-1-(4-methylphenyl)sulfonyl-2-aziridinemethanol (42) Tetrabutylammonium fluoride in THF (5.6 ml, 5.6 mmol; 1 M solution) was added by syringe to a stirred solution of the silyl ether **41** (2.58 g, 5.6 mmol) in 20 ml of THF at −78 °C, then the mixture was allowed to warm to 0 °C, and stirring was continued for 30 min. The mixture was poured into ice-water and extracted with CH_2Cl_2. The extract was washed with saturated brine, and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue, which was purified by flash chromatography over silica gel with *n*-hexane–EtOAc (1 : 1) to yield 1.45 g (74.4% yield) of the title compound **42** as a crystalline residue. Recrystallization from CH_2Cl_2–Et_2O (1 : 4) gave colorless crystals. mp 91 °C. $[\alpha]_D^{27}$ +24.6° (c = 0.78, $CHCl_3$). IR ($CHCl_3$): 3500 cm^{-1} (OH). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 2.03 (1H, tripletoid m), 2.43 (3H, s), 3.12 (2H, m), 3.52 (1H, dd, J = 10.8, 6.0 Hz), 3.58—3.73 (3H, m), 4.42 (1H, d, J = 11.8 Hz), 4.48 (1H, d, J = 11.8 Hz), 7.20—7.32 (7H, m), 7.79—7.83 (2H, m). *Anal.* Calcd for $C_{18}H_{21}NO_4S$: C, 62.23; H, 6.09; N, 4.03. Found: C, 62.13; H, 6.10; N, 4.02. (Data for racemic **42**, see ref. 11*b*)

(2*S*,3*S*)-4-Benzyloxy-1-*tert*-butyldimethylsilyloxy-2,3-epoxybutane (44) By use of a procedure identical with that described for the preparation of **20**, the epoxy alcohol **43**[14b] (388 mg, 2 mmol, 95% ee; Chiralcel OD; 2-propanol: *n*-hexane = 1 : 9) was converted into the title

compound **44** (515 mg, 83.5% yield) as a colorless oil. Kugelrohr distillation, 145 °C (1 mmHg). $[\alpha]_D^{20}$ −9.9° (c=0.703, $CHCl_3$). IR ($CHCl_3$): 1460, 1258, 1215, 839 cm^{-1}. ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.067 (3H, s), 0.074 (3H, s), 0.90 (9H, s), 3.01 (1H, m), 3.12 (1H, m), 3.50 (1H, dd, J=11.6, 5.6 Hz), 3.69 (1H, dd, J=12.0, 4.6 Hz), 3.76 (1H, dd, J=11.6, 3.1 Hz), 3.85 (1H, dd, J=12.0, 3.1 Hz), 4.55 (1H, d, J=12.0 Hz), 4.61 (1H, d, J=12.0 Hz), 7.26—7.35 (5H, m). *Anal.* Calcd for $C_{17}H_{20}O_3Si$: C, 66.19; H, 9.15. Found: C, 66.13; H, 9.36.

(2*R*,3*R*)-3-Azido-4-benzyloxy-1-*tert*-butyldimethylsiloxy-2-hydroxybutane (45) and (2*R*,3*R*)-2-Azido-4-benzyloxy-1-*tert*-butyldimethylsiloxy-3-hydroxy-butane (46) Sodium azide (325 mg, 5 mmol), followed by ammonium chloride (107 mg, 2 mmol),[21,22] was added to a stirred solution of the epoxy silyl ether **44** (308 mg, 1 mmol) in 5 ml of a 1:8 mixture of water and ethylene glycol monomethyl ether, and the mixture was heated under reflux for 3 h. The mixture was concentrated under reduced pressure, and the residual semisolid was extracted with $CHCl_3$. The extract was washed with brine and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue which was flash-chromatographed over silica gel. Elution with *n*-hexane–EtOAc (7:1) gave 77.3 mg (22% yield) of **45** as a colorless oil and further elution yielded 94.5 mg (27% yield) of **46** as a colorless oil. **45**: $[\alpha]_D^{20}$ −24.1° (c=0.810, $CHCl_3$). IR ($CHCl_3$): 2100 cm^{-1}. ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.08 (3H, s), 0.09 (3H, s), 0.90 (9H, s), 2.60 (1H, dd, J=12.0, 6.0 Hz), 3.57—3.66 (2H, m), 3.67—3.74 (3H, m), 3.84—3.91 (1H, m), 4.56—4.62 (2H, m), 7.25—7.36 (5H, m). LR-MS (FAB) m/z: 352 (MH^+), 324, 150, 117, 115, 91 (base peak), 73. HR-MS (FAB) m/z Calcd for $C_{17}H_{30}N_3O_3Si$ (MH^+): 352.2056. Found: 352.2064. **46**: $[\alpha]_D^{20}$ −25.1° (c=0.838, $CHCl_3$). IR ($CHCl_3$): 2100 cm^{-1}. ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.09 (6H, s), 0.91 (9H, s), 2.70 (1H, m), 3.51 (1H, ddd, J=10.1, 6.5, 3.6 Hz), 3.56 (1H, dd, J=9.7, 5.8 Hz), 3.63 (1H, dd, J=9.7, 3.7 Hz), 3.70—3.81 (1H, m), 3.84 (1H, dd, J=10.6, 6.4 Hz), 3.97 (1H, dd, J=10.6, 3.6 Hz), 4.57 (2H, s), 7.23—7.39 (5H, m). LR-MS (FAB) m/z: 352 (MH^+), 324, 264, 174, 116, 91 (base peak), 73. HR-MS (FAB) m/z Calcd for $C_{17}H_{30}N_3O_3Si$ (MH^+): 352.2056. Found: 352.2040.

(2*R*,3*R*)-3-Azido-4-benzyloxy-1,2-diacetoxybutane (47) By a procedure identical with that described for the synthesis of **39** from **37**, 25 mg (0.071 mmol) of **45** was converted into 15.6 mg (68% yield) of the title compound **47** as a colorless oil. $[\alpha]_D^{20}$ −32.3° (c=0.991, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 2.04 (3H, s), 2.05 (3H, s), 3.57 (1H, dd, J=10.0, 6.9 Hz), 3.67 (1H, dd, J=10.0, 3.6 Hz), 3.85 (1H, ddd, J=6.9, 6.9, 3.6 Hz), 4.16 (1H, dd, J=12.3, 5.9 Hz), 4.40 (1H, dd, J=12.3, 3.1 Hz), 4.54 (1H, d, J=12.0 Hz), 4.59 (1H, d, J=12.0 Hz), 5.12 (1H, ddd, J=5.9, 5.9, 3.1 Hz), 7.26—7.38 (5H, m). LR-MS (FAB) m/z: 322 (MH^+), 294, 149, 91 (base peak), 43. HR-MS (FAB) m/z Calcd for $C_{15}H_{20}N_3O_5$ (MH^+): 322.1403. Found: 322.1419.

(2*R*,3*R*)-2-Azido-4-benzyloxy-1,3-diacetoxybutane (48) By a procedure identical with that described for the synthesis of **39** from **37**, 35 mg (0.10 mmol) of **46** was converted into 26 mg (81% yield) of the title compound **48** as a colorless oil. $[\alpha]_D^{20}$ +2.76° (c=0.87, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 2.08 (3H, s), 2.09 (3H, s), 3.64 (1H, dd, J=10.8, 4.3 Hz), 3.69 (1H, dd, J=10.8, 4.3 Hz), 4.02 (1H, ddd, J=7.2, 7.2, 3.5 Hz), 4.20 (1H, dd, J=11.7, 7.2 Hz), 4.29 (1H, dd, J=11.7, 3.5 Hz), 4.52 (1H, d, J=12.5 Hz), 4.56 (1H, d, J=12.5 Hz), 5.03 (1H, ddd, J=6.8, 4.3, 4.3 Hz), 7.28—7.38 (5H, m). LR-MS (FAB) m/z: 322 (MH^+), 214, 192, 149, 91 (base peak), 43. HR-MS (FAB) m/z Calcd for $C_{15}H_{20}N_3O_5$ (MH^+): 322.1403. Found: 322.1400.

(2*S*,3*S*)-3-(Benzyloxy)methyl-2-(*tert*-butyldimethylsiloxy)methyl-1-[(4-methylphenyl)sulfonyl]aziridine (49) A mixture of triphenylphosphine (4.444 g, 16.94 mmol) and the azides **45** and **46** (45:55 mixture, 5.953 g, 16.94 mmol) in 15 ml of toluene was heated under reflux for 5 h, then allowed to cool. Triethylamine (3.54 ml, 25.41 mmol), followed by *p*-toluenesulfonyl chloride (4.84 g, 25.41 mmol), was added to the above mixture at 0 °C, and the whole was stirred at room temperature for 18 h. It was then cooled to 0 °C, and a saturated $NaHCO_3$ solution (50 ml) was added with vigorous stirring. This mixture was extracted with Et_2O and the extract was washed successively with 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The usual work-up followed by flash chromatography over silica gel with *n*-hexane–EtOAc (7:1) gave 6.71 g (85.8% yield) of the title compound **49** as a colorless oil. $[\alpha]_D^{20}$ −4.7° (c=0.565, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.62 (3H, s), 0.71 (3H, s), 0.91 (9H, s), 2.48 (3H, s), 3.02—3.13 (2H, m), 3.85—3.99 (4H, m), 4.56 (1H, d, J=12.2 Hz), 4.60 (1H, d, J=12.2 Hz), 7.31—7.40 (7H, m), 7.91—7.94 (2 H, m). LR-MS (FAB) m/z: 462 (MH^+), 446, 404, 270, 91 (base peak), 73. HR-MS (FAB) m/z Calcd for $C_{24}H_{36}NO_4SSi$ (MH^+): 462.2134. Found: 462.2143.

(2*S*,3*S*)-3-(Benzyloxy)methyl-1-(4-methylphenyl)sulfonyl-2-aziridinemethanol (50) Tetrabutylammonium fluoride in THF (1 ml, 1 mmol; 1 M solution) was added by syringe to a stirred solution of the silyl ether **49** (462 mg, 1 mmol) in 2 ml of THF at −78 °C, then the mixture was allowed to warm to 0 °C, and stirring was continued for 20 min. The mixture was poured into ice-water and extracted with CH_2Cl_2. The extract was washed with saturated brine and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue, which was purified by flash chromatography over silica gel with *n*-hexane–EtOAc (1:1) to give 310.3 mg (89.3% yield) of the title compound **50** as a crystalline residue. Recrystallization from *n*-hexane–Et_2O (1:10) gave colorless crystals. mp 39 °C. $[\alpha]_D^{20}$ +15.4° (c=1.12, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.62 (1H, br s), 2.42 (3H, s), 2.74 (1H, dd, J=9.1, 5.2 Hz), 3.05 (ddd, J=7.8, 4.5, 3.1 Hz), 3.25 (ddd, J=6.6, 4.4, 4.4 Hz), 3.50 (1H, dd, J=11.0, 6.6 Hz), 3.69 (1H, dd, J=11.0, 4.4 Hz), 3.94 (1H, ddd, J=13.2, 8.0, 5.2 Hz), 4.13 (1H, ddd, J=13.2, 9.2, 3.1 Hz), 4.40 (1H, d, J=12.0 Hz), 4.43 (1H, d, J=12.0 Hz), 7.16—7.19 (2H, m), 7.26—7.32 (5H, m), 7.83—7.87 (2H, m). LR-MS (FAB) m/z: 348 (MH^+), 240, 185, 155, 139, 91 (base peak), 75. HR-MS (FAB) m/z Calcd for for $C_{18}H_{22}NO_4S$ (MH^+): 348.1269. Found: 348.1287. (Data for racemic **50**, see ref. 11*b*)

Methyl *O*-*tert*-Butyldimethylsilyl-*N*-(4-methylphenyl)sulfonyl-(*R*)-serinate (51) Triethylamine (64.45 ml, 0.462 mol) was added dropwise to a stirred suspension of methyl (*R*)-serinate hydrochloride (36 g, 0.231 mol) and *p*-toluenesulfonyl chloride (43.89 g, 0.231 mol) in a mixed solvent of $CHCl_3$–CH_2Cl_2 (1:1, 200 ml) at 0 °C under argon. The mixture was stirred at 0 °C for 48 h. Imidazole (31.4 g, 0.462 mol), *tert*-butyldimethylsilyl chloride (34.9 g, 0.231 mol), and DMF (20 ml) were added successively to the stirred solution , and the whole was stirred for 20 h at 0 °C. It was then cooled to −20 °C, and a saturated NH_4Cl solution (100 ml) was added dropwise with vigorous stirring. The mixture was extracted with *n*-hexane and the extract was washed successively with 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The usual work-up followed by flash chromatography over silica gel with *n*-hexane–EtOAc (3:1) gave a crystalline residue. Recrystallization from *n*-hexane gave 57.5 g (64% yield) of the title compound **51** as colorless crystals. mp 56—57 °C. $[\alpha]_D^{18}$ −6.84° (c=1.72, $CHCl_3$). IR ($CHCl_3$): 3380, 1746 cm^{-1}. ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.015 (6H, s), 0.84 (9H, s), 2.43 (3H, s), 3.56 (3H, s), 3.78 (1H, dd, J=10.0, 3.5 Hz), 3.96 (1H, dd, J=10.0, 3.0 Hz), 4.04 (1H, ddd, J=9.1, 3.2, 3.2 Hz), 5.39 (1H, d, J=9.1 Hz), 7.28—7.31 (2H, m), 7.72—7.76 (2H, m). *Anal.* Calcd for $C_{17}H_{29}NO_5SSi$: C, 52.68; H, 7.54; N, 3.61. Found: C, 52.43; H, 7.56; N, 3.60.

***O*-*tert*-Butyldimethylsilyl-*N*-(4-methylphenyl)sulfonyl-(*R*)-serinol (52)** DIBAL in *n*-hexane (322 ml, 0.3 mol; 0.93 M solution) was added dropwise to a stirred solution of the ester **51** (38.7 g, 0.1 mol) in 150 ml of CH_2Cl_2 at −78 °C under argon. The mixture was allowed to warm to room temperature and stirring was continued for 18 h. The mixture was recooled to −78 °C, and a saturated NH_4Cl solution (100 ml) was added dropwise with vigorous stirring. The inorganic salts were removed by filtration through Celite. The filtrate was extracted with EtOAc and the extract was washed with water and dried over $MgSO_4$. The usual work-up and flash chromatography over silica gel with *n*-hexane–EtOAc (3:1) gave 18.4 g (51% yield) of the title compound **52** as a colorless oil. $[\alpha]_D^{25}$ −16.1° (c=1.22, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$) δ: −0.10 (3H, s), −0.09 (3H, s), 0.84 (9H, s), 2.43 (3H, s), 3.29 (1H, m), 3.50 (1H, dd, J=10.0, 4.9 Hz), 3.55 (1H, t, J=4.4 Hz), 3.64 (1H, dd, J=8.6, 4.2 Hz), 3.70 (1H, dd, J=9.8, 4.4 Hz), 5.17 (1H, d, J=8.0 Hz), 7.27—7.33 (2H, m), 7.75—7.79 (2H, m). LR-MS (FAB) m/z: 360 (MH^+, base peak), 344, 302, 288, 206, 184, 155, 139, 116, 91, 73. HR-MS (FAB) m/z Calcd for $C_{16}H_{30}NO_4SSi$ (MH^+): 360.1665. Found: 360.1648.

(2*S*)-2-(*tert*-Butyldimethylsiloxy)methyl-1-[(4-methylphenyl)sulfonyl]aziridine (53) Diethyl azodicarboxylate (4.17 g, 24 mmol) was added dropwise to a stirred mixture of the alcohol **52** (7.18 g, 20 mmol) and triphenylphosphine (6.29 g, 24 mmol) in 10 ml of THF at 0 °C, then the mixture was allowed to warm to room temperature and stirred at this temperature for 20 h. It was concentrated under reduced pressure to afford an oil, which was flash-chromatographed on a silica gel column. Elution with *n*-hexane–EtOAc (3:1) gave 3.25 g (48% yield) of the title compound **53** as a colorless oil. $[\alpha]_D^{25}$ −25.8° (c=0.823, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: −0.041 (3H, s), −0.024 (3H, s), 0.81 (9H, s), 2.20 (1H, d, J=4.5 Hz), 2.44 (3H, s), 2.64 (1H, d, J=7.0 Hz), 2.92 (1H, m), 3.59 (1H, dd, J=11.6, 5.3 Hz), 3.69 (1H, dd, J=11.6,

4.1 Hz), 7.26—7.33 (2H, m), 7.82—7.91 (2H, m). LR-MS (FAB) *m/z*: 342 (MH^+, base peak), 326, 284, 228, 185, 171, 155, 135, 93, 73. HR-MS (FAB) *m/z* Calcd for $C_{16}H_{28}NO_3SSi$ (MH^+): 342.1559. Found: 342.1567.

(2*S*)-2-Hydroxymethyl-1-[(4-methylphenyl)sulfonyl]aziridine (54) Tetrabutylammonium fluoride in THF (8.8 ml, 8.8 mmol; 1.0 M solution) was added by syringe to a stirred solution of silyl ether **53** (3.0 g, 8.8 mmol) in 3 ml of THF at 0 °C, and the mixture was stirred for 20 min at the same temperature. It was then poured into ice-water and extracted with EtOAc. The extract was successively washed with 5% citric acid, saturated brine, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. Concentration under reduced pressure gave an oily residue which was purified by flash chromatography over silica gel with *n*-hexane–EtOAc (1 : 1) to yield 2.0 g (99% yield) of the title compound **54** as a colorless oil. $[\alpha]_D^{25}$ −38.5° (*c* = 1.22, $CHCl_3$). ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 2.30 (1H, d, *J* = 4.6 Hz), 2.45 (3H, s), 2.61 (1H, d, *J* = 7.3 Hz), 3.02 (1H, m), 3.54 (1H, dd, *J* = 12.5, 5.3 Hz), 3.84 (1H, dd, *J* = 12.5, 3.3 Hz), 7.27—7.37 (2H, m), 7.81—7.84 (2H, m). LR-MS (FAB) *m/z*: 228 (MH^+, base peak), 184, 155, 139, 91, 72. HR-MS (FAB) *m/z* Calcd for $C_{10}H_{14}NO_3S$ (MH^+): 228.0694. Found: 228.0687.

Methyl *O*-*tert*-Butyldimethylsilyl-*N*-(methane)sulfonyl-(*S*)-serinate (55) Diisopropylethylamine (69 ml, 0.386 mol), followed by methanesulfonyl chloride (14.9 ml, 0.193 mol), was added dropwise to a stirred suspension of methyl (*S*)-serinate hydrochloride (30 g, 0.193 mol) in 150 ml of CH_2Cl_2 at −78 °C. The mixture was allowed to warm to 0 °C and stirred at this temperature for 2 h. Then imidazole (43.3 g, 0.637 mol), *tert*-butyldimethylsilyl chloride (32 g, 0.21 mol), and DMF (100 ml) were added successively, and the mixture was stirred for 48 h at 0 °C. It was then cooled to −20 °C, and a saturated $NaHCO_3$ solution (100 ml) was added dropwise with vigorous stirring. The mixture was extracted with a mixed solvent of Et_2O–EtOAc (1 : 1) and the extract was washed successively with 5% citric acid, water, 5% $NaHCO_3$, and water, and dried over $MgSO_4$. The usual work-up followed by flash chromatography over silica gel with *n*-hexane–EtOAc (4 : 1) gave 47 g (78% yield) of the title compound **55** as a colorless oil. $[\alpha]_D^{26}$ −8.07° (*c* = 1.86, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.01 (3H, s), 0.026 (3H, s), 0.84 (9H, s), 2.98 (3H, s), 3.75 (3H, s), 3.83 (1H, dd, *J* = 10.0, 3.3 Hz), 4.04 (1H, dd, *J* = 10.0, 3.3 Hz), 4.20 (1H, ddd, *J* = 9.2, 3.3, 3.3 Hz), 5.33 (1H, d, *J* = 9.2 Hz). *Anal.* Calcd for $C_{11}H_{25}NO_5SSi$: C, 42.42; H, 8.09; N, 4.50. Found: C, 42.17; H, 8.18; N, 4.46.

***O*-*tert*-Butyldimethylsilyl-*N*-methanesulfonyl-(*S*)-serinol (56)** DIBAL in toluene (300 ml, 0.3 mol; 1 M solution) was added dropwise to a stirred solution of the ester **55** (31.1 g, 0.1 mol) in 100 ml of CH_2Cl_2 at −78 °C under argon. The mixture was allowed to warm to room temperature and stirring was continued for 18 h. The mixture was recooled to −78 °C, and a saturated NH_4Cl solution (40 ml) was added dropwise with vigorous stirring. The inorganic salts were removed by filtration through Celite. The filtrate was extracted with EtOAc and the extract was washed with water and dried over $MgSO_4$. The usual work-up and flash chromatography over silica gel with *n*-hexane–EtOAc (1 : 1) gave 17 g (60% yield) of the title compound **56** as a colorless oil. $[\alpha]_D^{29}$ +10.0° (*c* = 0.723, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 0.08 (3H, s), 0.09 (3H, s), 0.90 (9H, s), 2.82 (1H, br s), 3.03 (3H, s), 3.51 (1H, m), 3.74 (4H, m), 5.21 (1H, d, *J* = 8.1 Hz). LR-MS (FAB) *m/z*: 284 (MH^+, base peak), 226, 152, 131, 108, 73. HR-MS (FAB) *m/z* Calcd for $C_{10}H_{26}NO_4SSi$ (MH^+): 284.1352. Found: 284.1360.

(2*R*)-2-(*tert*-Butyldimethylsiloxy)methyl-1-methanesulfonylaziridine (57) Diethyl azodicarboxylate (2.61 g, 15 mmol) was added dropwise to a stirred mixture of the alcohol **56** (2.83 g, 10 mmol) and triphenylphosphine (3.93 g, 15 mmol) in 20 ml of THF at 0 °C, then the mixture was allowed to warm to room temperature and stirred at this temperature for 48 h. It was then concentrated under reduced pressure to afford an oil, which was flash-chromatographed on a silica gel column. Elution with *n*-hexane–EtOAc (4 : 1) gave 1.45 g (55% yield) of the title compound **57** as a colorless oil. Kugelrohr distillation, 140 °C (1 mmHg). $[\alpha]_D^{27}$ +49.8° (*c* = 0.833, $CHCl_3$). ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 0.08 (6H, s), 0.90 (9H, s), 2.24 (1H, d, *J* = 4.6 Hz), 2.64 (1H, d, *J* = 7.3 Hz), 2.87 (1H, m), 3.07 (3H, s), 3.56 (1H, dd, *J* = 11.1, 6.2 Hz), 3.87 (1H, dd, *J* = 11.1, 3.8 Hz). *Anal.* Calcd for $C_{10}H_{23}NO_3SSi$: C, 45.25; H, 8.73; N, 5.28. Found: C, 45.27; H, 8.89; N, 5.38.

(2*R*)-2-Hydroxymethyl-1-methanesulfonylaziridine (58) A 46% aqueous solution of hydrofluoric acid (1.1 ml) was added dropwise by syringe to a stirred solution of the silyl ether **57** (265 mg, 1 mmol) in 2 ml of MeCN at −78 °C, then the mixture was allowed to warm to 0 °C and stirred at this temperature for 4 h. It was filtered through a short alumina column. Elution with EtOAc and concentration of the eluate under reduced pressure afforded a colorless oily residue, which was purified by flash chromatography over silica gel with EtOAc to yield 100 mg (66% yield) of the title compound **58** as a colorless oil. Kugelrohr distillation, 120 °C (1 mmHg). $[\alpha]_D^{28}$ +53.4° (*c* = 0.705, $CHCl_3$). ^{1}H-NMR (270 MHz, $CDCl_3$) δ: 2.01 (1H, dd, *J* = 6.9, 5.6 Hz), 2.38 (1H, d, *J* = 4.6 Hz), 2.64 (1H, d, *J* = 7.3 Hz), 3.00 (1H, m), 3.10 (3H, s), 3.60 (1H, ddd, *J* = 12.2, 6.9, 5.3 Hz), 3.98 (1H, ddd, *J* = 12.2, 5.6, 3.0 Hz). LR-MS (FAB) *m/z*: 152 (MH^+, base peak), 108. HR-MS (FAB) *m/z* Calcd for $C_4H_{10}NO_3S$ (MH^+): 152.0381. Found: 152.0384.

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