Pergamon

Tetrahedron 58 (2002) 7109–7117

TETRAHEDRON

Aziridine–allylsilane-mediated synthesis of exocyclic γ-amino olefins and azabicyclo[*x*.*y*.1]-systems

David J. Lapinsky and Stephen C. Bergmeier*

Department of Chemistry and Biochemistry, Ohio University, Athens, OH 45701, USA

Dedicated to the memory of Professor Henry Rapoport (1918–2002)

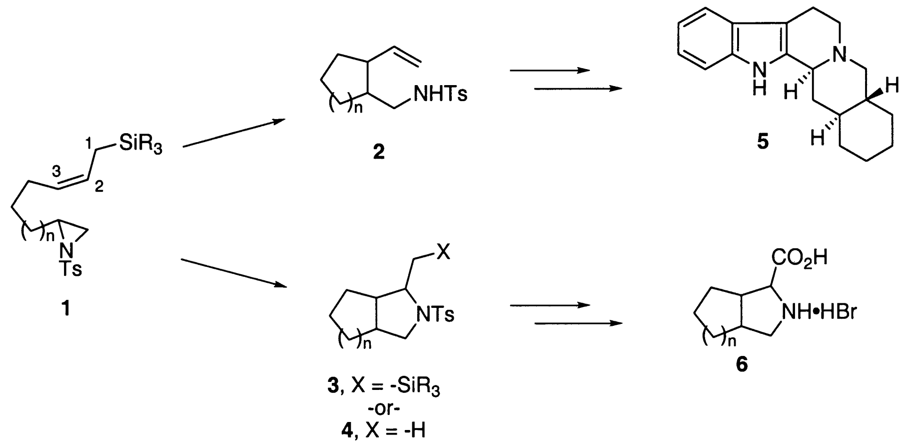
Received 15 April 2002; accepted 9 May 2002

Abstract—We have shown that connection of *C*-2 of an allylsilane to a tethered aziridine ring yields exocyclic γ-amino olefins and desilylated azabicyclo[*x*.2.1]-systems upon cyclization with $BF_3{\cdot}OEt_2$. Furthermore, manipulation of a specific exocyclic γ-amino olefin provided access to an azabicyclo[3.3.1]nonane. This methodology should be useful for the preparation of natural products and pharmacologically active agents containing these bicyclic heterocyclic systems. © 2002 Elsevier Science Ltd. All rights reserved.

General methodology for the synthesis of alkaloids and other nitrogen containing heterocycles continues to be of immense importance to the pharmaceutical sciences. In this regard, we have discovered a method that could serve as a general and useful procedure for the synthesis of these molecules. We have reported the conversion of an aziridine–allylsilane (**1**) to either the γ-amino olefin[1] (**2**), the silylated azabicycle[1c] (**3**), or the desilylated azabicycle (**4**). Molecules **2** and **3** have served as instrumental intermediates toward our synthesis of the rauwolfia alkaloid (−)-yohimbane[1b] (**5**) and bicyclic proline analogs[1c] (**6**) (Scheme 1).

Although aziridine–allylsilane **1** represents an example of *C*-3 of the allylsilane tethered to an aziridine ring, we felt connection to *C*-2 of the allylsilane could also produce synthetically useful products. Treatment of aziridine–allylsilanes with this connectivity (e.g. **7**) could potentially lead to the isolation of exocyclic γ-amino olefins (**8**), silylated azabicyclo[*x*.2.1]-systems (**9**), or desilylated azabicyclo[*x*.2.1]-systems (**10**) (Scheme 2).

These cyclization products could be useful in either total or analog synthesis of complex natural products and pharmacologically active agents containing 6-azabicyclo-[3.2.1]octanes[2] or 3-azabicyclo[3.3.1]nonanes.[2d,3] For example, Thomas et al. reported[2d] the synthesis of a 1,5-disubstituted-6-azabicyclo[3.2.1]octane (**11**) in order to explore the effect of ring E contraction on nicotinic acetylcholine receptor antagonist activity of methyllycaconitine (MLA)

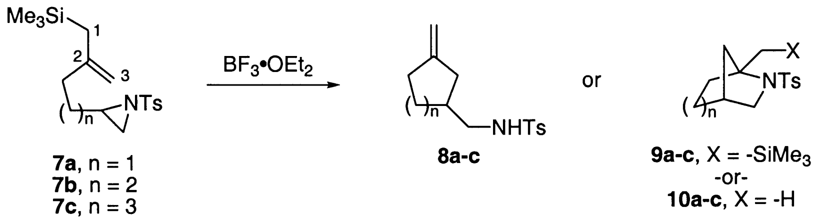


Scheme 1.

Keywords: aziridines; allylsilanes; bicyclic heterocyclic compounds; nitrogen heterocycles.

* Corresponding author. Fax: +1-740-593-0148; e-mail: bergmeis@ohio.edu

PII: S0040-4020(02)00725-1



Scheme 2.

(**12**). Appropriate manipulation of olefin **8b** could lead to the inherent azabicyclo[3.3.1]nonane (**13**) present within the AE rings of MLA (**12**) (Fig. 1). With these thoughts in mind, we chose to prepare and cyclize a series of aziridine–allylsilanes possessing the *C*-2 connectivity (**7a–c**). Our synthesis of these compounds was carried out via Suzuki coupling of an appropriately substituted aziridine with an allylsilane,[4] or via nucleophilic attack of an aziridine with an organometallic allylsilane reagent.[1b,c,5]

We initially prepared a racemic aziridine–allylsilane (**7b**) possessing the desired *C*-2 connectivity as a test substrate to explore the cyclization reaction. Commercially available allylglycine was treated with MeOH/HCl followed by toluenesulfonyl chloride to provide the diprotected amino acid **14**[6] in 80% yield from allylglycine. The ester was then reduced with LiBH$_4$ followed by a Mitsunobu ring closure to provide aziridine **16**. The olefin of **16** was hydroborated with 9-BBN and cross-coupled to bromoallylsilane **17**[7] to give the racemic aziridine–allylsilane **7b** in 58% yield. The racemic substrate was then treated with 110 mol% of BF$_3$·OEt$_2$ at −78°C for 4 h, then warmed to −25°C for an additional 15 h. We were pleased to find that these cyclization conditions provided the racemic exocyclic γ-amino olefin **8b** in 86% yield. This cyclization proceeded as expected with attack of the allylsilane at the internal carbon of the aziridine ring, thus yielding the six-membered carbocycle. The desilylated azabicyclo[3.2.1]-system (**10b**, racemic) was also isolated in low yield (6%) (Scheme 3).

The results of the initial cyclization of racemic aziridine–allylsilane **7b** prompted us to examine a series of optically pure aziridine–allylsilanes with *C*-2 connectivity ((*R*)-**7a–c**), differing only in the length of tether between the reacting moieties. Two of the aziridines ((*R*)-**7b** and (*R*)-**7c**) were readily prepared using our Suzuki strategy.[4] Serine derived

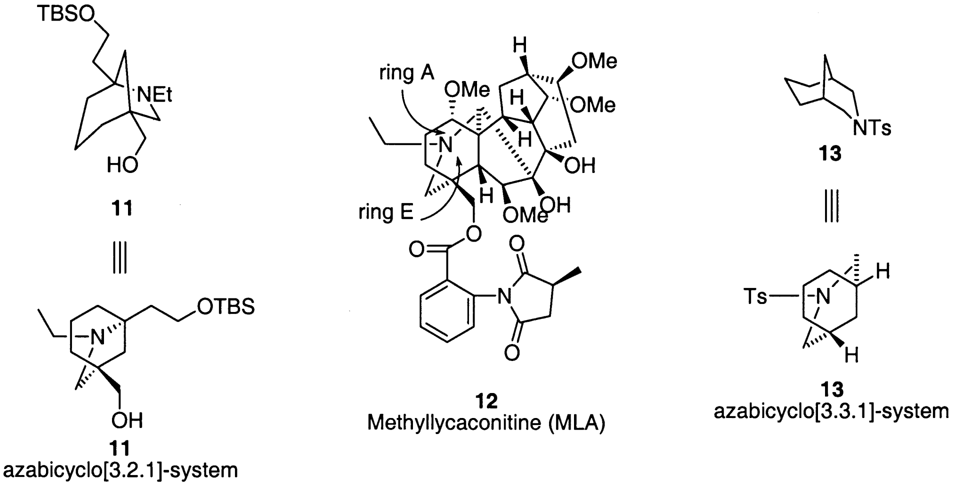
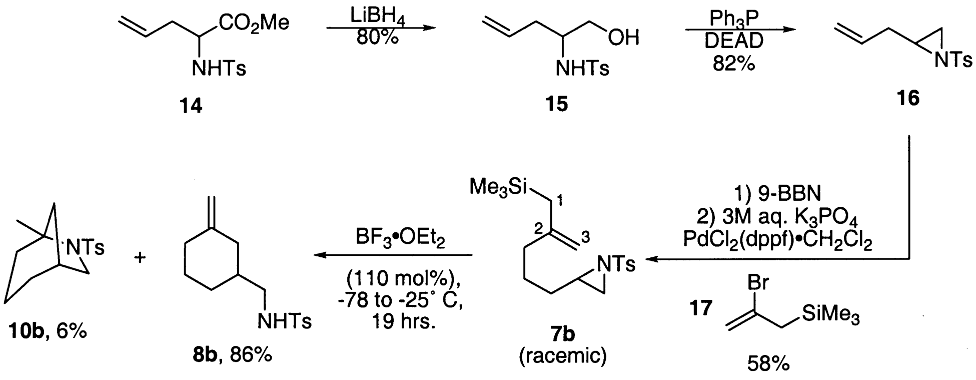
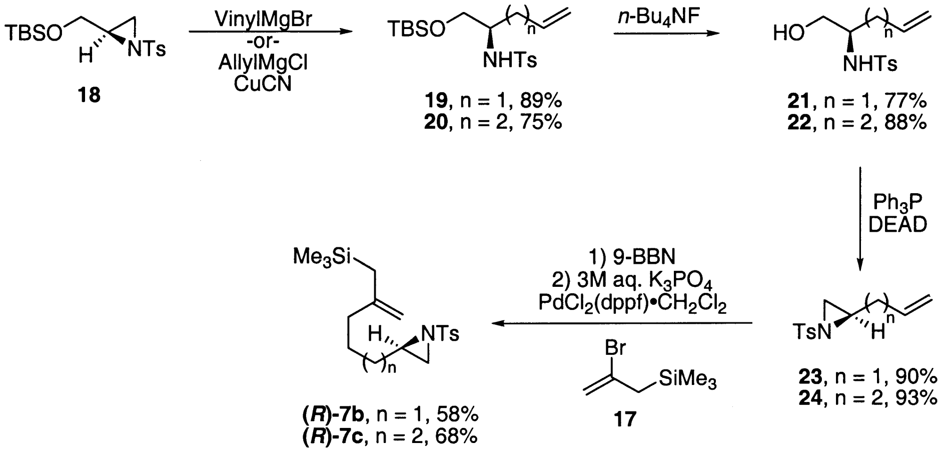


Figure 1.



Scheme 3.

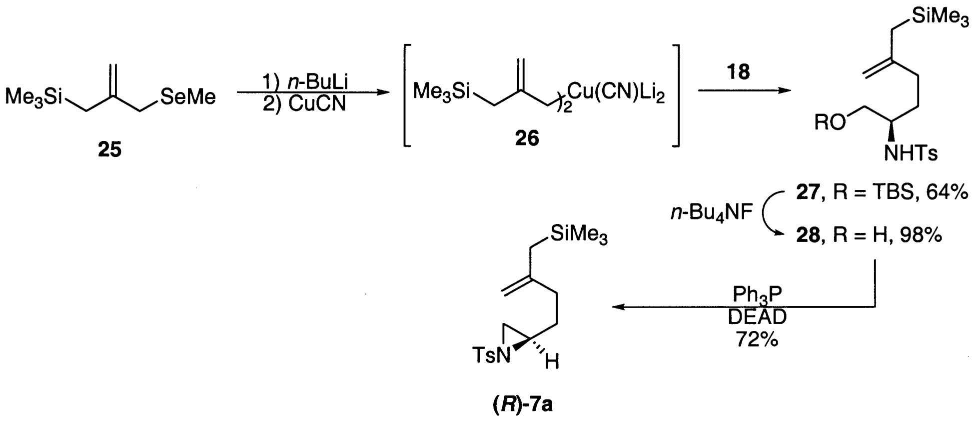


Scheme 4.

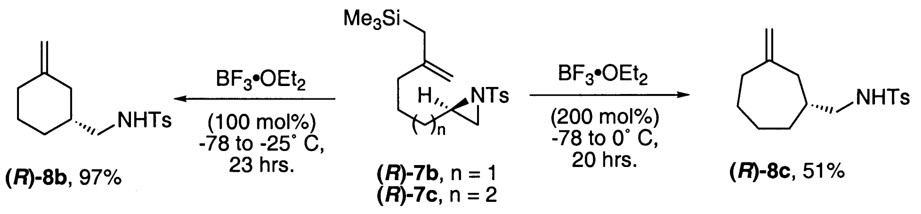
aziridine **18**[5] was treated with either vinylmagnesium bromide or allylmagnesium chloride in the presence of CuCN to yield the desired silyl ether homologs (**19** and **20**). Removal of the silyl protecting group and Mitsunobu ring closure provided olefinic aziridines **23** and **24**[8] in excellent overall yield. Standard cross-coupling conditions using bromoallylsilane **17** provided optically pure aziridine–allylsilanes (*R*)-**7b** and (*R*)-**7c** in 58% and 68% yield, respectively (Scheme 4).

The remaining aziridine–allylsilane of interest to us ((*R*)-**7a**) could not be accessed via the Suzuki cross-coupling route.[4] Therefore we turned our attention towards nucleophilic attack of aziridine **18** with an organometallic allylsilane reagent.[1b,c,5] The known allylselenide **25** was subjected to Li–Se exchange[9] then transmetallated in the presence of CuCN[10] to generate the higher order cyanocuprate **26**. Reaction of aziridine **18** with the organometallic allylsilane reagent provided the ring opened product **27** in 64% yield. Deprotection with *n*-Bu$_4$NF followed by a Mitsunobu reaction formed the aziridine ring to yield aziridine–allylsilane (*R*)-**7a** in good overall yield (Scheme 5).

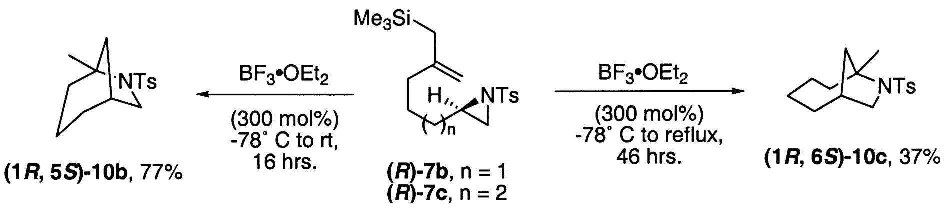
With our requisite aziridine–allylsilanes in hand, we began to explore cyclization conditions to selectively yield exocyclic γ-amino olefins. Treatment of aziridine–allylsilane (*R*)-**7b** with a stoichiometric amount of $BF_3{\cdot}OEt_2$ at −78°C, followed by warming of the reaction to −25°C, provided the exocyclic olefin (*R*)-**8b** in nearly quantitative yield (97%). Aziridine–allylsilane (*R*)-**7c** was cyclized in a similar manner, though additional $BF_3{\cdot}OEt_2$ (200 mol%) and higher temperatures (0°C) were needed for cyclization to the seven-membered ring to occur. Exocyclic olefin (*R*)-**8c** was achieved in moderate yield (51%) after purification. The other major product (ca. 35%) of the reaction appears to be the product of protodesilylation of (*R*)-**7c** and proved difficult to isolate cleanly (Scheme 6).



Scheme 5.



Scheme 6.

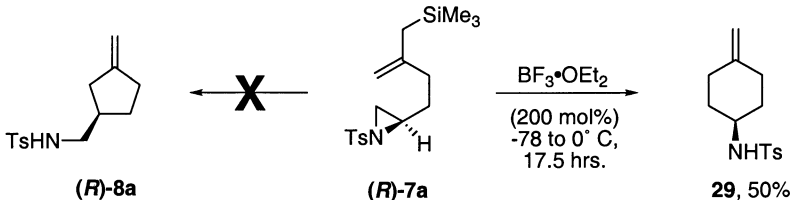


Scheme 7.

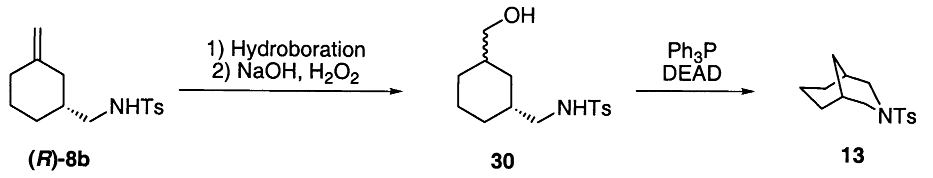
Aziridine–allylsilanes (*R*)-**7b** and (*R*)-**7c** were then cyclized with greater than stoichiometric amounts of $BF_3 \cdot OEt_2$ (300 mol%) and warmed to room temperature in the hopes of forming azabicyclo[*x*.2.1]-systems. After subjecting substrate (*R*)-**7b** to these conditions, we were able to isolate the desilylated azabicyclo[3.2.1]octane (1*R*,5*S*)-**10b** in good yield (77%), while a 1:1:1 mixture of isomerized amino olefins was obtained in 15% yield. Treatment of aziridine–allylsilane (*R*)-**7c** in a similar manner gave a 1:1:1 mixture of isomerized amino olefins as the major product (54% yield), while the desilylated azabicyclo[4.2.1]nonane (1*R*,6*S*)-**10c** was achieved in only 31% yield. We hoped refluxing conditions could potentially drive the mixture of amino olefins towards bicycle (1*R*,6*S*)-**10c** formation, though minimal changes in yield were observed (51 and 37% for yields of isomerized olefins and (1*R*,6*S*)-**10c**, respectively) (Scheme 7). It remains unclear as to how these desilylated azabicyclo[*x*.2.1]-systems are being formed. Three possibilities exist: (1) desilylated azabicyclo[*x*.2.1]-systems **10b**,**c** could form via cyclization of the aziridine–allylsilane to the silylated azabicycle (i.e. **9b**,**c**) followed by protodesilylation, (2) cyclization of the aziridine-olefin (i.e. protodesilylated (*R*)-**7b**,**c**), or (3) cyclization of the γ-amino olefin (exocyclic or isomerized (*R*)-**8b**,**c**). We suggest that option (2) or (3) are the most likely. We have determined that protodesilylated (*R*)-**7b** can be cyclized to azabicyclo[3.2.1]octane (1*R*,5*S*)-**10b** (71% yield) using 300 mol% of $BF_3 \cdot OEt_2$ at room temperature. We have also determined that γ-amino olefins (e.g. **2**) can be cyclized to their azabicyclic counterpart (e.g. **4**) under similar conditions.[11]

Cyclizations of aziridine–allylsilanes (*R*)-**7b** and (*R*)-**7c** proceeded with attack of the allylsilane at the internal carbon of the aziridine ring, which is consistent with previously reported intramolecular cyclizations of aziridine–allylsilanes.[1] However, substrate (*R*)-**7a** provided an alternative cyclization behavior. Treatment of this aziridine–allylsilane with 200 mol% of $BF_3 \cdot OEt_2$ and warming to 0°C gave the six-membered ring **29** as the major product (50% yield) (Scheme 8). Products resulting from attack of the internal carbon of the aziridine (i.e. (*R*)-**8a**) were not observed, only those resulting from attack of the terminal position. Therefore, aziridine–allylsilane (*R*)-**7a** displays comparable reactivity to that reported for allylsilane-epoxides possessing identical tether length and *C*-2 connectivity.[12] Additionally, protodesilylation of (*R*)-**7a** was detected by ^{1}H NMR though purification of this product (ca. 37%) again proved troublesome.

In an effort to extend the synthesis of azabicyclo[*x*.*y*.1]-systems, olefin (*R*)-**8b** was subjected to a hydroboration-oxidation sequence to provide a mixture of *cis* and *trans* amino alcohols (**30**). The mixture of alcohols was cyclized under Mitsunobu conditions to provide the azabicyclo-[3.3.1]nonane (**13**) resulting from closure of the *cis* amino alcohol. When olefin (*R*)-**8b** was hydroborated with 9-BBN, ^{1}H NMR of the crude reaction mixture showed a 1:1 mixture



Scheme 8.



	cis:trans[a]	yield from (R)-8b
9-BBN	1:1	51%
$BH_3 \cdot THF$	1:2	30%

via ^{1}H NMR of crude reaction mixture[a]

Scheme 9.

of *cis* and *trans* amino alcohols. Subsequent Mitsunobu ring closure provided the azabicycle **13** in 51% yield from olefin (*R*)-**8b**. However, when BH_3·THF was used in the hydroboration a 1:2 mixture of *cis* and *trans* amino alcohols was observed, thus providing only 30% yield of **13** after the Mitsunobu reaction. Aziridine–allylsilane (*R*)-**7b** proved to be a valuable intermediate towards both azabicyclo[3.2.1] and [3.3.1]-systems (Scheme 9).

In conclusion, we have shown that connection of *C*-2 of an allylsilane to a tethered aziridine ring yields exocyclic γ-amino olefins and desilylated azabicyclo[*x*.2.1]-systems upon cyclization with $BF_3\cdot OEt_2$. Furthermore, manipulation of a specific exocyclic γ-amino olefin provided access to an azabicyclo[3.3.1]nonane. This methodology should be useful for the preparation of natural products and pharmacologically active agents containing these bicyclic heterocyclic systems.

1. Experimental

1.1. General

^{1}H spectra were recorded on a Bruker AG 250 MHz spectrometer. ^{13}C spectra were recorded on a Varian VX 400 MHz spectrometer. Chemical shifts are reported in ppm relative to $CDCl_3$ (7.27 for ^{1}H, 77.23 for ^{13}C) or C_6D_6 (7.16 for ^{1}H, 128.39 for ^{13}C). Coupling constants (*J*) are reported in Hz. Thin layer chromatography (TLC) was performed on EM Science pre-coated silica gel 60 F_{254} aluminum foils. Purification of the reaction products was carried out by flash chromatography using a glass column dry packed with silica gel (ICN SiliTech 32-63D 60 Å) according to the method of Still.[13] Visualization was accomplished with UV light, I_2, and/or phosphomolybdic acid solution followed by heating. HRMS measurements were determined at the Ohio State University Chemical Instrument Center with a Kratos MS-30 mass spectrometer in the electron impact (EI) mode. Optical activity was measured on an Autopol IV automatic polarimeter. THF and Et_2O were distilled from sodium and benzophenone. DMF, CH_2Cl_2, and $BF_3\cdot OEt_2$ were distilled from CaH_2 before use. Et_3N was distilled from CaH_2 and stored over KOH pellets. All reactions were carried out in flame-dried glassware under an Ar atmosphere unless otherwise specified.

1.1.1. *N*-[(4-Methylphenyl)sulfonyl]-2-amino-4-pentenol (15). Dry LiCl (0.99 g, 23.4 mmol) was added to a stirred solution of ester **14**[6] (2.21 g, 7.81 mmol) in THF (10.9 mL) and EtOH (21.8 mL). The mixture was cooled to 0°C and $NaBH_4$ (0.89 g, 23.4 mmol) was added over 5 min. After the addition, the ice bath was removed and the mixture was warmed to room temperature and stirred for an additional 14 h. The reaction was quenched with acetone and concentrated to a white residue, which was carefully dissolved in 1 M HCl: EtOAc (ca. 1:1). The layers were separated and the aqueous layer was extracted with EtOAc. The combined organic layers were washed with brine, dried ($MgSO_4$), filtered, concentrated, and chromatographed (40% EtOAc in hexanes) to give 1.60 g of alcohol **15** (80%). R_f 0.27 (40% EtOAc in hexanes). ^{1}H NMR ($CDCl_3$, 250 MHz) δ 7.77 (d, 2H, J=8.78 Hz), 7.29 (d, 2H, J=8.78 Hz), 5.55–5.38 (m, 1H), 5.37 (d, 1H, J=7.83 Hz), 4.99–4.93 (m, 2H), 3.62–3.48 (m, 2H), 3.29 (m, 1H), 2.69 (br s, 1H), 2.41 (s, 3H), 2.16 (m, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 143.4, 137.4, 133.3, 129.5, 127.0, 118.3, 63.9, 54.9, 35.8, 21.4. HRMS for $C_{12}H_{17}NO_3S\cdot Na^+$ calcd 278.0821, found 278.0823.

1.1.2. 2-[2-Propenyl]-*N*-[(4-methylphenyl)sulfonyl]aziridine (16). Ph_3P (1.81 g, 6.90 mmol) was added to a stirred solution of alcohol **15** (1.60 g, 6.27 mmol) in THF (24.7 mL). The mixture was cooled to 0°C and diethyl azodicarboxylate (1.1 mL, 6.90 mmol) was added dropwise. After the addition, the ice bath was removed and the reaction was warmed to room temperature and stirred for an additional 16 h. The mixture was concentrated and chromatographed (8–15% EtOAc in hexanes) to give 1.23 g of aziridine **16** (82%). R_f 0.21 (15% EtOAc in hexanes). ^{1}H NMR ($CDCl_3$, 250 MHz) δ 7.82 (d, 2H, J=7.80 Hz), 7.33 (d, 2H, J=8.80 Hz), 5.68–5.52 (m, 1H), 5.10–4.95 (m, 2H), 2.80 (m, 1H), 2.63 (d, 1H, J=6.85 Hz), 2.44 (s, 3H), 2.31–2.14 (m, 2H), 2.10 (d, 1H, J=3.90 Hz). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 144.4, 134.9, 132.7, 129.5, 127.8, 117.5, 39.1, 35.0, 33.0, 21.5. HRMS for $C_{12}H_{15}NO_2S\cdot Na^+$ calcd 260.0716, found 260.0710.

1.1.3. 2-[4-[(Trimethylsilyl)methyl]-4-pentenyl]-*N*-[(4-methylphenyl)sulfonyl]aziridine (7b, racemic). A stirred solution of olefin **16** (0.42 g, 1.77 mmol) in THF (6.1 mL) was cooled to 0°C and treated with 9-BBN (4.3 mL, 0.5 M in THF, 2.13 mmol). After the addition, the ice bath was removed and the mixture was warmed to room temperature and stirred for an additional 3 h. DMF (3.1 mL) and K_3PO_4 (1.2 mL, 3 M in H_2O, 3.72 mmol) were added followed quickly by the addition of (2-bromoallyl)trimethylsilane **17**[7] (0.3 mL, 1.95 mmol). $PdCl_2$(dppf) ·CH_2Cl_2 (0.07 g, 0.09 mmol) was added and the mixture stirred at room temperature for 18.5 h, then concentrated to the DMF layer. The residue was taken up in Et_2O and washed with H_2O. The layers were separated and the aqueous layer was extracted with Et_2O (×2). The combined organic layers were washed with sat. aq. $NaHCO_3$ solution, dried ($MgSO_4$), filtered, concentrated, and chromatographed (100% benzene) to give 0.36 g of racemic aziridine–allylsilane **7b** (58%). R_f 0.31 (10% EtOAc in hexanes). ^{1}H NMR (C_6D_6, 250 MHz) δ 7.89 (d, 2H, J=8.78 Hz), 6.73 (d, 2H, J=7.83 Hz), 4.59 (app s, 2H), 2.71–2.62 (m, 1H), 2.44 (d, 1H, J=6.85 Hz), 1.86 (s, 3H), 1.80 (t, 2H, J=6.85 Hz), 1.52 (d, 1H, J=4.88 Hz), 1.41 (s, 2H), 1.35–0.96 (m, 4H), 0.01 (s, 9H). ^{13}C NMR (C_6D_6, 100 MHz) δ 146.9, 143.8, 136.8, 129.6, 128.3, 107.7, 40.0, 37.8, 33.5, 31.1, 26.6, 25.2, 21.1, −1.3. HRMS for $C_{18}H_{29}NO_2SSi\cdot Na^+$ calcd 378.1530, found 378.1538.

1.1.4. 3-(*N*-[(4-Methylphenyl)sulfonyl]aminomethyl)-1-methylenecyclohexane (8b, racemic). A stirred solution of racemic aziridine **7b** (0.94 g, 2.68 mmol) in CH_2Cl_2 (26.8 mL) was cooled to −78°C and treated with freshly distilled $BF_3\cdot OEt_2$ (0.2 mL, 1.34 mmol). After 1 h at −78°C another 0.6 eq. (0.2 mL, 1.61 mmol) of $BF_3\cdot OEt_2$ was added. The reaction was stirred at −78°C for 3 h then maintained at −25°C for 15 h. The reaction was quenched with sat. aq. $NaHCO_3$ solution then warmed to room temperature. The layers were separated and the aqueous layer was extracted with CH_2Cl_2. The combined organic layers were dried ($MgSO_4$), filtered, concentrated, and chromatographed (25% Et_2O in hexanes) to first provide 44.7 mg of racemic desilylated bicycle **10b** (6%), followed by 0.64 g of racemic exocyclic olefin **8b** (86%). R_f 0.49 for racemic desilylated bicycle **10b**, 0.41 for racemic exocyclic olefin **8b** (25% EtOAc in hexanes). ^1H NMR (C_6D_6, 250 MHz) δ 7.90 (d, 2H, J=8.78 Hz), 6.84 (d, 2H, J=7.83 Hz), 5.26 (t, 1H, J=6.85 Hz), 4.62 (d, 2H, J=4.88 Hz), 2.67 (t, 2H, J=5.85 Hz), 2.19–2.01 (m, 2H), 1.92 (s, 3H), 1.79–1.66 (m, 1H), 1.54–1.32 (m, 4H), 1.17–1.03 (m, 1H), 0.87–0.72 (m, 1H). ^{13}C NMR (C_6D_6, 100 MHz) δ 147.7, 142.9, 138.4, 129.7, 127.5, 108.3, 48.8, 39.1, 38.9, 35.0, 29.8, 26.6, 21.1. HRMS for $C_{15}H_{21}NO_2S{\cdot}Na^+$ 302.1185, found 302.1169.

1.1.5. (2*R*)-1-(*tert*-Butyldimethylsilyl)oxo-*N*-[(4-methylphenyl)sulfonyl]-2-amino-4-pentene (19). Vinylmagnesium bromide (30.6 mL, 1 M in THF, 30.60 mmol) was added to a -78°C slurry of CuCN (0.50 g, 5.64 mmol) in Et_2O (34 mL). After stirring for 20 min, a solution of aziridine **18**[5] (3.44 g, 10.07 mmol) in THF (51 mL) was added via cannula. After the addition, the mixture was maintained at 0°C for 4 days then quenched with a solution composed of 10% conc. NH_4OH/90% sat. aq. NH_4Cl solution. The mixture was diluted with Et_2O and stirred at room temperature until all solids were dissolved (ca. 4 h). The layers were separated and the aqueous layer was extracted with Et_2O. The combined organic layers were washed with brine, dried ($MgSO_4$), filtered, concentrated, and chromatographed (10% EtOAc in hexanes) to give 3.31 g of silyl ether **19** (89%). R_f 0.32 (15% EtOAc in hexanes), $[\alpha]_D^{24}$=+17.9° (c 1.1, EtOAc). ^1H NMR ($CDCl_3$, 250 MHz) δ 7.75 (d, 2H, J=7.80 Hz), 7.30 (d, 2H, J=8.80 Hz), 5.68–5.51 (m, 1H), 5.04–4.98 (m, 2H), 4.75 (d, 1H, J=7.80 Hz), 3.53–3.48 (m, 1H), 3.39–3.33 (m, 1H), 3.28 (m, 1H), 2.43 (s, 3H), 2.25 (t, 2H, J=6.83 Hz), 0.85 (s, 9H), -0.01 (s, 3H), -0.03 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 143.2, 137.8, 133.6, 129.5, 127.0, 118.2, 63.4, 54.2, 36.2, 25.7, 21.4, 18.1, -5.7. HRMS for $C_{18}H_{31}NO_3SSi{\cdot}Na^+$ calcd 392.1686, found 392.1706.

1.1.6. (2*R*)-1-(*tert*-Butyldimethylsilyl)oxo-*N*-[(4-methylphenyl)sulfonyl]-2-amino-5-hexene (20). Allylmagnesium chloride (30.5 mL, 2 M in THF, 60.94 mmol) was added to a -78°C slurry of CuCN (1.01 g, 11.23 mmol) in Et_2O (67.7 mL). After stirring for 20 min, a solution of aziridine **18**[5] (6.85 g, 20.05 mmol) in THF (101.6 mL) was added via cannula. After the addition, the reaction was maintained at 0°C for 45 h then quenched with a solution composed of 10% conc. NH_4OH/90% sat. aq. NH_4Cl solution. The mixture was diluted with Et_2O and stirred at room temperature until all solids were dissolved (ca. 6 h). The layers were separated and the aqueous layer was extracted with Et_2O. The combined organic layers were washed with brine, dried ($MgSO_4$), filtered, concentrated, and chromatographed (10% EtOAc in hexanes) to give 5.80 g of silyl ether **20** (75%). R_f 0.24 (10% EtOAc in hexanes), $[\alpha]_D^{25}$=+25.4° (c 2.7, EtOAc). ^1H NMR ($CDCl_3$, 250 MHz) δ 7.75 (d, 2H, J=8.78 Hz), 7.29 (d, 2H, J=8.78 Hz), 5.79–5.63 (m, 1H), 4.98–4.90 (m, 2H), 4.81 (d, 1H, J=7.80 Hz), 3.44–3.29 (m, 2H), 3.24 (m, 1H), 2.42 (s, 3H), 2.07–1.96 (m, 2H), 1.61–1.52 (m, 2H), 0.84 (s, 9H), -0.03 (s, 3H), -0.05 (s, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 143.2, 138.3, 137.7, 129.6, 127.0, 115.0, 64.0, 54.4, 31.4, 29.7, 25.8, 21.4, 18.2, -5.6. HRMS for $C_{19}H_{33}NO_3SSi{\cdot}Na^+$ calcd 406.1843, found 406.1855.

1.1.7. (2*R*)-*N*-[(4-Methylphenyl)sulfonyl]-2-amino-4-pentenol (21). A stirred solution of silyl ether **19** (4.70 g, 12.71 mmol) in THF (30.1 mL) was cooled to 0°C and treated with n-Bu_4NF (14.0 mL, 1 M in THF, 13.98 mmol). After 2 h at 0°C the reaction was partitioned between H_2O and Et_2O. The layers were separated and the aqueous layer was extracted with Et_2O. The combined organic layers were washed with brine, dried ($MgSO_4$), filtered, concentrated, and chromatographed (40% EtOAc in hexanes) to give 2.49 g of alcohol **21** (77%). Analytical data was the same as that reported for **15** except $[\alpha]_D^{24}$=-3.5° (c 2.4, EtOAc).

1.1.8. (2*R*)-*N*-[(4-Methylphenyl)sulfonyl]-2-amino-5-hexenol (22). A stirred solution of silyl ether **20** (5.80 g, 15.12 mmol) in THF (30.2 mL) was cooled to 0°C and treated with n-Bu_4NF (16.6 mL, 1 M in THF, 16.63 mmol). After 1 h at 0°C the reaction was partitioned between H_2O and Et_2O. The layers were separated and the aqueous layer was extracted with Et_2O. The combined organic layers were washed with brine, dried ($MgSO_4$), filtered, concentrated, and chromatographed (40% EtOAc in hexanes) to give 3.59 g of alcohol **22** (88%). R_f 0.33 (50% EtOAc in hexanes), $[\alpha]_D^{24}$=+3.5° (c 2.8, EtOAc). ^1H NMR ($CDCl_3$, 250 MHz) δ 7.79 (d, 2H, J=8.80 Hz), 7.31 (d, 2H, J=7.83 Hz), 5.68–5.51 (m, 1H), 5.37 (d, 1H, J=8.80 Hz), 4.90–4.81 (m, 2H), 3.61–3.45 (m, 2H), 3.26 (m, 1H), 2.48 (br s, 1H), 2.42 (s, 3H), 2.03–1.78 (m, 2H), 1.61–1.38 (m, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 143.5, 137.7, 137.3, 129.7, 127.1, 115.2, 64.5, 55.0, 30.8, 29.6, 21.5. HRMS for $C_{13}H_{19}NO_3S{\cdot}Na^+$ calcd 292.0978, found 292.0972.

1.1.9. (2*R*)-2-[2-Propenyl]-*N*-[(4-methylphenyl)sulfonyl]-aziridine (23). Ph_3P (1.27 g, 4.83 mmol) was added to a stirred solution of alcohol **21** (1.12 g, 4.39 mmol) in THF (22.0 mL). The mixture was cooled to 0°C and diethyl azodicarboxylate (0.8 mL, 4.83 mmol) was added dropwise. After the addition, the ice bath was removed and reaction was warmed to room temperature and stirred for an additional 4 h. The mixture was concentrated and chromatographed (8% to 15% EtOAc in hexanes) to give 0.94 g of aziridine **23** (90%). Analytical data was the same as that reported for **16** except $[\alpha]_{365}^{24}$=+18.9° (c 4.3, EtOAc).

1.1.10. (2*R*)-2-[3-Butenyl]-*N*-[(4-methylphenyl)sulfonyl]-aziridine (24). Ph_3P (0.78 g, 2.96 mmol) was added to a stirred solution of alcohol **22** (0.72 g, 2.69 mmol) in THF (13.5 mL). The mixture was cooled to 0°C and diethyl azodicarboxylate (0.5 mL, 2.96 mmol) was added dropwise. After the addition, the ice bath was removed and reaction was warmed to room temperature and stirred for an additional 4 h. The mixture was concentrated and chromatographed (15% EtOAc in hexanes) to give 0.63 g of aziridine **24** (93%). R_f 0.32 (15% EtOAc in hexanes), $[\alpha]_D^{25}$=-7.0° (c 3.6, EtOAc). ^1H NMR ($CDCl_3$, 250 MHz) δ 7.83 (d, 2H, J=7.80 Hz), 7.34 (d, 2H, J=8.78 Hz), 5.81–5.65 (m, 1H), 5.01–4.93 (m, 2H), 2.75 (m, 1H), 2.63 (d, 1H, J=6.83 Hz), 2.44 (s, 3H), 2.08 (d, 1H, J=4.90 Hz), 2.09–1.99 (m, 2H), 1.72–1.58 (m, 1H), 1.52–1.37 (m, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 144.4, 136.9, 135.1, 129.6, 127.9, 115.5, 39.7, 33.8, 30.7, 30.6, 21.6. HRMS for $C_{13}H_{17}NO_2S\cdot Na^+$ calcd 274.0872, found 274.0860.

1.1.11. (2*R*)-2-[4-[(Trimethylsilyl)methyl]-4-pentenyl]-*N*-[(4-methylphenyl)sulfonyl]aziridine ((*R*)-7b). Aziridine–allylsilane (*R*)-**7b** was prepared using aziridine **23** (0.42 g, 1.77 mmol) following the same procedure as reported for racemic **7b**. This reaction provided 0.36 g of (*R*)-**7b** (58%). Analytical data was the same as that reported for **7b** except $[\alpha]^{22}_{365}$=+14.5° (*c* 0.9, EtOAc).

1.1.12. (2*R*)-2-[5-[(Trimethylsilyl)methyl]-5-hexenyl]-*N*-[(4-methylphenyl)sulfonyl]aziridine ((*R*)-7c). A stirred solution of olefin **24** (0.98 g, 3.90 mmol) in THF (13.4 mL) was cooled to 0°C and treated with 9-BBN (8.6 mL, 0.5 M in THF, 4.29 mmol). After the addition, the ice bath was removed and the mixture was warmed to room temperature and stirred for an additional 7 h. (2-Bromoallyl)trimethylsilane **17**[7] (0.84 g, 4.34 mmol), DMF (5.0 mL), K_3PO_4 (2.7 mL, 3 M in H_2O, 8.18 mmol), and $PdCl_2(dppf)\cdot CH_2Cl_2$ (0.16 g, 0.19 mmol) were added to a separate flask and the organoborane solution was added via cannula with an additional DMF (1.7 mL) rinsing. After the addition, the reaction was stirred at room temperature for 25 h then poured into Et_2O and washed with H_2O and brine. The aqueous layers were extracted with Et_2O (×3). The combined organic layers were dried ($MgSO_4$), filtered, concentrated, and chromatographed (50% hexanes in benzene then 100% benzene) to give 0.96 g of aziridine–allylsilane (*R*)-**7c** (68%). R_f 0.34 (Benzene), $[\alpha]^{24}_{365}$= +16.2° (*c* 7.5, EtOAc). ^{1}H NMR ($CDCl_3$, 250 MHz) δ 7.81 (d, 2H, *J*=7.80 Hz), 7.32 (d, 2H, *J*=8.80 Hz), 4.51 (app s, 1H), 4.48 (app s, 1H), 2.71 (m, 1H), 2.62 (d, 1H, *J*= 6.83 Hz), 2.43 (s, 3H), 2.05 (d, 1H, *J*=4.88 Hz), 1.85 (t, 2H, *J*=7.80 Hz), 1.47 (s, 2H), 1.59–1.16 (m, 6H), 0.00 (s, 9H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 147.1, 144.3, 135.1, 129.6, 127.9, 107.0, 40.3, 37.9, 33.7, 31.2, 27.1, 26.6, 26.4, 21.6, −1.4. HRMS for $C_{19}H_{31}NO_2SSi\cdot Na^+$ calcd 388.1737, found 388.1735.

1.1.13. (2*R*)-1-(*tert*-Butyldimethylsilyl)oxo-*N*-[(4-methylphenyl)sulfonyl]-2-amino-5-(trimethylsilyl)methyl-5-hexene (27). A solution of allylselenide **25**[9] (1.44 g, 6.51 mmol) in THF (4.3 mL) was added dropwise to a −78°C stirred solution of *n*-BuLi (3.3 mL, 1.96 M in hexanes, 6.51 mmol). After 40 min the allyllithium solution was transferred via cannula into a flask containing a −78°C slurry of CuCN (0.29 g, 3.25 mmol) in THF (3.8 mL). After 8 min the mixture was warmed to 0°C and stirred for 1 h. The reaction was recooled to −78°C and a solution of aziridine **18**[5] (0.74 g, 2.17 mmol) in THF (2.3 mL) was added via cannula. After the addition, the reaction was maintained at 0°C for 22.5 h then quenched with a solution composed of 10% conc. NH_4OH/90% sat. aq. NH_4Cl solution. The mixture was diluted with Et_2O then stirred at room temperature to allow the solids to dissolve. The layers were separated and the aqueous layer was extracted with Et_2O (×3). The combined organic layers were washed with H_2O, brine, dried ($MgSO_4$), filtered, concentrated, and chromatographed (100% hexanes then 100% benzene) to give 0.66 g of allylsilane silyl ether **27** (64%). R_f 0.29 (Benzene), $[\alpha]^{24}_{D}$=+16.5° (*c* 4.3, EtOAc). ^{1}H NMR (C_6D_6, 250 MHz) δ 7.85 (d, 2H, *J*=7.83 Hz), 6.81 (d, 2H, *J*=7.83 Hz), 4.99 (d, 1H, *J*=7.80 Hz), 4.65 (s, 1H), 4.61 (s, 1H), 3.51–3.32 (m, 3H), 2.03–1.72 (m, 3H), 1.93 (s, 3H), 1.63–1.51 (m, 1H), 1.45 (s, 2H), 0.88 (s, 9H), 0.02 (s, 6H), −0.03 (s, 9H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.6, 143.1, 138.2, 129.6, 127.0, 107.3, 64.0, 54.7, 34.1, 30.2, 26.6, 25.8, 21.4, 18.2, −1.4, −5.6. HRMS for $C_{23}H_{43}NO_3SSi_2\cdot Na^+$ calcd 492.2394, found 492.2403.

1.1.14. (2*R*)-*N*-[(4-Methylphenyl)sulfonyl]-2-amino-5-(trimethylsilyl)methyl-5-hexenol (28). A stirred solution of silyl ether **27** (1.87 g, 3.97 mmol) in THF (4.1 mL) was cooled to 0°C and treated with *n*-Bu_4NF (4.4 mL, 1 M in THF, 4.37 mmol). The reaction was stirred for 30 min at 0°C then partitioned between H_2O and Et_2O. The layers were separated and the aqueous layer was extracted with Et_2O. The combined organic layers were washed with brine, dried ($MgSO_4$), filtered, concentrated, and chromatographed (60% Et_2O in hexanes) to give 1.39 g of alcohol **28** (98%). R_f 0.24 (30% EtOAc in hexanes), $[\alpha]^{24}_{365}$=−4.9° (*c* 7.4, EtOAc). ^{1}H NMR (C_6D_6, 250 MHz) δ 7.94 (d, 2H, *J*=7.83 Hz), 6.89 (d, 2H, *J*=8.78 Hz), 5.94 (d, 1H, *J*= 7.80 Hz), 4.57 (s, 1H), 4.55 (s, 1H), 3.72–3.64 (m, 1H), 3.56–3.48 (m, 1H), 3.37–3.35 (m, 1H), 3.20 (t, 1H, *J*= 5.88 Hz), 1.95 (s, 3H), 1.92–1.51 (m, 4H), 1.35 (s, 2H), −0.02 (s, 9H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.2, 143.3, 137.8, 129.7, 127.1, 107.4, 64.5, 55.4, 34.1, 29.6, 26.5, 21.5, −1.5. HRMS for $C_{17}H_{29}NO_3SSi\cdot Na^+$ calcd 378.1530, found 378.1513.

1.1.15. (2*R*)-2-[3-[(Trimethylsilyl)methyl]-3-butenyl]-*N*-[(4-methylphenyl)sulfonyl]aziridine ((*R*)-7a). Ph_3P (0.98 g, 3.72 mmol) was added to a stirred solution of alcohol **28** (1.20 g, 3.38 mmol) in THF (13.3 mL). The mixture was cooled to 0°C and diethyl azodicarboxylate (0.6 mL, 3.72 mmol) was added dropwise. After the addition, the ice bath was removed and the reaction was warmed to room temperature and stirred for an additional 2.5 h. The mixture was concentrated and chromatographed (2% to 15% EtOAc in hexanes) to give 0.82 g of aziridine (*R*)-**7a** (72%). R_f 0.37 (15% EtOAc in hexanes), $[\alpha]^{24}_{D}$= −10.2° (*c* 5.8, EtOAc). ^{1}H NMR (C_6D_6, 250 MHz) δ 7.88 (d, 2H, *J*=8.78 Hz), 6.74 (d, 2H, *J*=8.80 Hz), 4.57 (s, 2H), 2.74–2.64 (m, 1H), 2.44 (d, 1H, *J*=6.85 Hz), 1.86 (s, 3H), 1.83 (t, 2H, *J*=7.80 Hz), 1.54 (d, 1H, *J*=4.88 Hz), 1.53–1.38 (m, 1H), 1.35 (s, 2H), 1.33–1.09 (m, 1H), −0.04 (s, 9H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 145.9, 144.4, 135.1, 129.6, 128.0, 107.4, 40.1, 35.1, 33.7, 29.6, 26.8, 21.6, −1.5. HRMS for $C_{17}H_{27}NO_2SSi\cdot Na^+$ calcd 360.1424, found 360.1411.

1.1.16. (3*R*)-3-(*N*-[(4-Methylphenyl)sulfonyl]aminomethyl)-1-methylenecyclohexane ((*R*)-8b). A stirred solution of aziridine (*R*)-**7b** (0.53 g, 1.52 mmol) in CH_2Cl_2 (15.2 mL) was cooled to −78°C and treated with freshly distilled $BF_3\cdot OEt_2$ (0.2 mL, 1.52 mmol). The reaction was stirred for 1 h at −78°C then maintained at −25°C for 22 h. The reaction was quenched with sat. aq. $NaHCO_3$ solution then warmed to room temperature. The layers were separated and the aqueous layer was extracted with CH_2Cl_2. The combined organic layers were dried ($MgSO_4$), filtered, concentrated, and chromatographed (25% Et_2O in hexanes) to give 0.41 g of exocyclic olefin (*R*)-**8b** (97%). Analytical data was the same as that reported for **8b** except $[\alpha]^{23}_{D}$=−21.5° (*c* 1.8, EtOAc).

1.1.17. (3*R*)-3-(*N*-[(4-Methylphenyl)sulfonyl]aminomethyl)-1-methylenecycloheptane ((*R*)-8c). A stirred solution of aziridine (*R*)-**7c** (0.37 g, 1.0 mmol) in CH_2Cl_2 (10.0 mL) was cooled to −78°C and treated with freshly distilled $BF_3·OEt_2$ (0.3 mL, 2.0 mmol). The reaction was stirred for 1 h at −78°C then maintained at 0°C for 19 h. The reaction was quenched with sat. aq. $NaHCO_3$ solution then warmed to room temperature. The layers were separated and the aqueous layer was extracted with CH_2Cl_2. The combined organic layers were dried ($MgSO_4$), filtered, concentrated, and chromatographed (25% Et_2O in hexanes) to give 0.15 g of exocyclic olefin (*R*)-**8c** (51%). R_f 0.40 (25% EtOAc in hexanes), $[\alpha]_D^{24}=+7.5°$ (*c* 2.2, EtOAc). ^1H NMR ($CDCl_3$, 250 MHz) δ 7.75 (d, 2H, *J*=8.78 Hz), 7.30 (d, 2H, *J*=8.80 Hz), 4.88 (t, 1H, *J*=5.85 Hz), 4.69 (app s, 1H), 4.64 (app s, 1H), 2.79 (t, 2H, *J*=6.83 Hz), 2.42 (s, 3H), 2.38–2.24 (m, 1H), 2.18–1.85 (m, 2H), 1.72–1.57 (m, 5H), 1.42–1.07 (m, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 148.9, 143.2, 137.0, 129.6, 127.0, 112.0, 49.0, 39.3, 39.2, 36.1, 32.7, 28.2, 26.8, 21.5. ^1H and ^{13}C NMR also contained signals representing a small amount (ca. <5%) of isomerized amino olefin. HRMS for $C_{16}H_{23}NO_2S·Na^+$ calcd 316.1342, found 316.1338.

1.1.18. (1*R*,5*S*)-5-Methyl-6-[(4-methylphenyl)sulfonyl]-6-azabicyclo[3.2.1]octane ((1*R*,5*S*)-10b). A stirred solution of allylsilane (*R*)-**7b** (0.38 g, 1.07 mmol) in CH_2Cl_2 (10.8 mL) was cooled to −78°C and treated with freshly distilled $BF_3·OEt_2$ (0.4 mL, 3.22 mmol). After the addition, the ice bath was removed and the reaction was stirred at room temperature for 16 h then quenched with sat. aq. $NaHCO_3$ solution and diluted with CH_2Cl_2. The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (×2). The combined organic layers were dried ($MgSO_4$), filtered, concentrated, and chromatographed (15% EtOAc in hexanes) to give 0.23 g of (1*R*,5*S*)-**10b** (77%). R_f 0.49 (25% EtOAc in hexanes), $[\alpha]_D^{24}=-6.4°$ (*c* 2.2, EtOAc). ^1H NMR (C_6D_6, 250 MHz) δ 7.82 (d, 2H, *J*=8.78 Hz), 6.83 (d, 2H, *J*=8.80 Hz), 3.52 (d, 1H, *J*=9.76 Hz), 3.24–3.18 (m, 1H), 2.19–2.12 (m, 1H), 1.94 (s, 3H), 1.88–1.66 (m, 2H), 1.45 (s, 3H), 1.36–1.25 (m, 3H), 1.11–0.99 (m, 3H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 142.3, 139.9, 129.3, 126.5, 66.4, 54.4, 47.2, 37.8, 32.4, 29.9, 24.9, 21.4, 19.3. HRMS for $C_{15}H_{21}NO_2S·Na^+$ calcd 302.1185, found 302.1189.

1.1.19. (1*R*,6*S*)-6-Methyl-7-[(4-methylphenyl)sulfonyl]-7-azabicyclo[4.2.1]nonane ((1*R*,6*S*)-10c). A stirred solution of aziridine (*R*)-**7c** (0.38 g, 1.04 mmol) in CH_2Cl_2 (10.4 mL) was cooled to −78°C and treated with freshly distilled $BF_3·OEt_2$ (0.4 mL, 3.11 mmol). After the addition, the ice bath was removed and the reaction was stirred at room temperature for 23 h then refluxed for 23 h. The reaction was diluted with CH_2Cl_2 and quenched with sat. aq. $NaHCO_3$ solution. The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (×2). The combined organic layers were dried ($MgSO_4$), filtered, concentrated, and chromatographed (15% EtOAc in hexanes) to give 0.11 g of (1*R*,6*S*)-**10c** (37%). R_f 0.46 (25% EtOAc in hexanes), $[\alpha]_D^{24}=-7.9°$ (*c* 3.5, EtOAc). ^1H NMR (C_6D_6, 250 MHz) δ 7.82 (d, 2H, *J*=7.80 Hz), 6.85 (d, 2H, *J*=8.78 Hz), 3.29 (d, 1H, *J*=9.78 Hz), 3.19–3.12 (m, 1H), 2.69–2.58 (m, 1H), 1.95 (s, 3H), 1.86–1.71 (m, 1H), 1.69–1.12 (m, 9H), 1.43 (s, 3H). ^{13}C NMR (C_6D_6, 100 MHz) δ 142.1, 139.9, 129.4, 127.5, 68.6, 56.4, 43.7, 40.8, 34.9, 33.5, 28.8, 25.5, 23.9, 21.1. HRMS for $C_{16}H_{23}NO_2S·Na^+$ calcd 316.1342, found 316.1330.

1.1.20. 4-(*N*-[(4-Methylphenyl)sulfonyl]amino)-1-methylenecyclohexane (29). A stirred solution of aziridine (*R*)-**7a** (0.18 g, 0.54 mmol) in CH_2Cl_2 (5.4 mL) was cooled to −78°C and treated with freshly distilled $BF_3·OEt_2$ (0.1 mL, 1.09 mmol). The reaction was stirred at −78°C for 1 h then maintained at 0°C for 16.5 h. The mixture was quenched with sat. aq. $NaHCO_3$ solution then warmed to room temperature. The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (×2). The combined organic layers were dried ($MgSO_4$), filtered, concentrated, and chromatographed (25% Et_2O in hexanes) to give 71.6 mg of olefin **29** (50%). R_f 0.37 (25% EtOAc in hexanes). ^1H NMR ($CDCl_3$, 250 MHz) δ 7.79 (d, 2H, *J*=7.83 Hz), 7.30 (d, 2H, *J*=8.80 Hz), 4.84 (d, 1H, *J*=6.83 Hz), 4.60 (app s, 2H), 3.35–3.21 (m, 1H), 2.43 (s, 3H), 2.26–2.17 (m, 2H), 2.05–1.93 (m, 2H), 1.86–1.68 (m, 2H), 1.38–1.23 (m, 2H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 146.5, 143.2, 138.2, 129.6, 126.9, 108.3, 51.8, 34.4, 32.4, 21.5. HRMS for $C_{14}H_{19}NO_2S·Na^+$ calcd 288.1029, found 288.1032.

1.1.21. (1*R*,5*S*)-3-[(4-Methylphenyl)sulfonyl]-3-azabicyclo-[3.3.1]nonane (13): using 9-BBN. A solution of olefin (*R*)-**8b** (0.55 g, 1.98 mmol) in THF (4.1 mL) was treated with 9-BBN (15.8 mL, 0.5 M in THF, 7.91 mmol) at room temperature and stirred for 6.5 h. The reaction was then cooled to 0°C and treated with EtOH (4.65 mL) dropwise, followed by stirring for 5 min to quench the excess 9-BBN. 6N aq. NaOH (1.6 mL) was then added dropwise followed by 30% H_2O_2 (2.9 mL). After the addition, the mixture was refluxed for 1 h, cooled to room temperature and diluted with H_2O and EtOAc. The layers were separated and the aqueous layer was extracted with EtOAc (×2). The combined organic layers were washed with brine, dried ($MgSO_4$), filtered, and concentrated. ^1H NMR of the crude reaction mixture indicated a 1:1 mixture of *cis* and *trans* amino alcohols **30**. The crude mixture was chromatographed (50% EtOAc in hexanes) to give 0.59 g of a mixture of alcohols **30** (100%), which was immediately used in the Mitsunobu reaction. Ph_3P (0.57 g, 2.18 mmol) was added to a stirred solution of the alcohol mixture **30** (0.59 g, 1.98 mmol) in THF (7.8 mL). The mixture was cooled to 0°C and diethyl azodicarboxylate (0.3 mL, 2.18 mmol) was added dropwise. After the addition, the ice bath was removed and the reaction was warmed to room temperature and stirred for an additional 17 h. The mixture was concentrated and chromatographed (4–10% EtOAc in hexanes) to give 0.28 g of bicycle **13** (51% from (*R*)-**8b**).

1.1.22. Using $BH_3·THF$. A stirred solution of olefin (*R*)-**8b** (0.52 g, 1.85 mmol) in THF (3.8 mL) was treated with $BH_3·THF$ (7.4 mL, 1 M in THF, 7.41 mmol) at 0°C then warmed to room temperature and stirred for an additional 6.5 h. The above oxidation protocol was followed using EtOH (4.7 mL), 6N aq. NaOH (1.5 mL), and 30% H_2O_2 (2.7 mL). Standard work up gave 0.54 g of a 1:2 mixture (via crude ^1H NMR) of *cis* and *trans* amino alcohols **30** (99%), which was immediately used in the Mitsunobu reaction. Ph_3P (0.53 g, 2.02 mmol) was added to a stirred solution of the alcohol mixture **30** (0.54 g, 1.83 mmol) in

THF (7.2 mL). The mixture was cooled to 0°C and treated with diethyl azodicarboxylate (0.3 mL, 2.02 mmol) dropwise. After the addition, the ice bath was removed and the reaction was warmed to room temperature and stirred for an additional 15 h. The mixture was concentrated and chromatographed (4–10% EtOAc in hexanes) to give 0.15 g of bicycle **13** (30% from (*R*)-**8b**). R_f 0.43 (25% EtOAc in hexanes). ^{1}H NMR ($CDCl_3$, 250 MHz) δ 7.61 (d, 2H, J=7.50 Hz), 7.31 (d, 2H, J=7.50 Hz), 3.75 (d, 2H, J=11.73 Hz), 2.51–2.42 (m, 3H), 2.42 (s, 3H), 1.89–1.85 (m, 4H), 1.73–1.44 (m, 4H), 1.36–1.30 (m, 1H). ^{13}C NMR ($CDCl_3$, 100 MHz) δ 143.1, 132.5, 129.4, 127.6, 51.1, 32.4, 30.6, 28.0, 21.4, 20.8. HRMS for $C_{15}H_{21}NO_2S{\cdot}Na^+$ calcd 302.1185, found 302.1169.

References

1. (a) Bergmeier, S. C.; Seth, P. P. *Tetrahedron Lett.* **1995**, *36*, 3793–3796. (b) Bergmeier, S. C.; Seth, P. P. *J. Org. Chem.* **1999**, *64*, 3237–3243. (c) Bergmeier, S. C.; Fundy, S. L.; Seth, P. P. *Tetrahedron* **1999**, *55*, 8025–8038.
2. (a) Tamura, O.; Yanagimachi, T.; Kobayashi, T.; Ishibashi, H. *Org. Lett.* **2001**, *3*, 2427–2429. (b) Liras, S.; Davoren, J. E.; Bordner, J. *Org. Lett.* **2001**, *3*, 703–706. (c) Rigby, J. H.; Pigge, F. C. *Synlett* **1996**, *7*, 631–632. (d) Callis, D. J.; Thomas, N. F.; Pearson, D. P. J.; Potter, B. V. L. *J. Org. Chem.* **1996**, *61*, 4634–4640.
3. (a) Coates, P. A.; Blagbrough, I. S.; Rowan, M. G.; Potter, B. V. L. *Tetrahedron Lett.* **1994**, *35*, 8709–8712. (b) Udding, J. H.; Papin, N.; Hiemstra, H.; Speckamp, W. N. *Tetrahedron* **1994**, *50*, 8853–8862. (c) Risch, N.; Langhals, M.; Mikosch, W.; Bogge, H.; Muller, A. *J. Am. Chem. Soc.* **1991**, *113*, 9411–9412. (d) Jeyaraman, R.; Avila, S. *Chem. Rev.* **1981**, *81*, 149–174.
4. Bergmeier, S. C.; Lapinsky, D. J. *Tetrahedron Lett.* **2001**, *42*, 8583–8586.
5. Bergmeier, S. C.; Seth, P. P. *J. Org. Chem.* **1997**, *62*, 2671–2674.
6. (a) Voigtmann, U.; Blechert, S. *Synthesis* **2000**, *6*, 893–898. (b) Varray, S.; Gauzy, C.; Lamaty, F.; Lazaro, R.; Martinez, J. *J. Org. Chem.* **2000**, *65*, 6787–6790. (c) Witulski, B.; Gossman, M. *Chem. Commun.* **1999**, *18*, 1879–1880. (d) Bolton, G. L.; Hodges, J. C.; Rubin, J. R. *Tetrahedron* **1997**, *53*, 6611–6634.
7. (2-Bromoallyl)trimethylsilane is commercially available from Aldrich Chemical Co. or can easily be prepared via: Trost, B. M.; Grese, T. A.; Chan, D. M. T. *J. Am. Chem. Soc.* **1991**, *113*, 7350–7362.
8. Kim, S. H.; Fuchs, P. L. *Tetrahedron Lett.* **1996**, *37*, 2545–2548.
9. Ryter, K.; Livinghouse, T. *J. Org. Chem.* **1997**, *62*, 4842–4844.
10. For an example of CuI transmetallation with allylselenide **25** see: Ryter, K.; Livinghouse, T. *J. Am. Chem. Soc.* **1998**, *120*, 2658–2659.
11. Bergmeier, S. C.; Fundy, S. L.; McPherson, H. Unpublished results.
12. (a) Xiao, X.; Park, S.; Prestwich, G. D. *J. Org. Chem.* **1988**, *53*, 4869–4872. (b) Petterson, L.; Frejd, T.; Magnusson, G. *Tetrahedron Lett.* **1987**, *28*, 2753–2756. (c) Molander, G. A.; Shubert, D. C. *J. Am. Chem. Soc.* **1987**, *109*, 576–578. (d) Armstrong, R. J.; Weiler, L. *Can. J. Chem.* **1986**, *64*, 584–596.
13. Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923–2925.