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One-Pot Construction of Multiple Contiguous Chiral Centers Using Michael Addition of Chiral Amine

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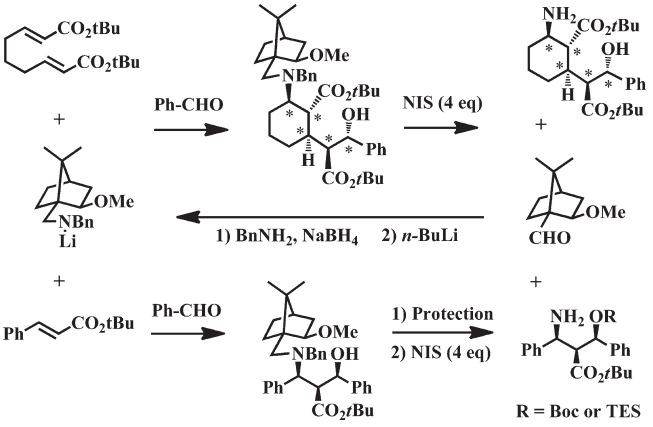

Multiple contiguous chiral centers were constructed in one pot using three types of multistep reactions initiated with the Michael addition of *N*-benzyl-2(*R*)-methoxy-(+)-10-bornylamide to α,β-unsaturated esters, i.e., asymmetric Michael−aldol reaction, double Michael addition, and double Michael−aldol reaction. The chiral 2-methoxy-10-bornyl group as well as the benzyl group on the amino group of the products in the Michael−aldol reaction could be easily cleaved by treatment with NIS (4 equiv), and β-amino esters with multiple contiguous chiral centers were obtained in good yield. As an application, the β-amino-β′-hydroxy ester obtained in the asymmetric Michael−aldol reaction was converted to the β-lactam derivative in good yield.

Introduction

Recently, one-pot multistep reactions[1] have been developed for the asymmetric synthesis of complex compounds having several chiral centers. For instance, Davies achieved one-pot construction of three contiguous chiral centers in a cyclic amine, which was initiated by the Michael addition of α-phenethyl amide to nona-2,7-diene-1,9-diate, followed by intramolecular Michael addition.[2] Enders succeeded in one-pot construction of eight contiguous chiral centers by designing the double Michael-aldol reaction initiated by adding Jørgensen's catalyst[3] to perform a subsequent intramolecular Diels−Alder reaction.[4] Moreover, other types of domino reaction initiated by Michael addition have been developed by other research groups.[5−7]

We also developed a tandem Michael addition−MPV reduction, which was initiated with the Michael addition of

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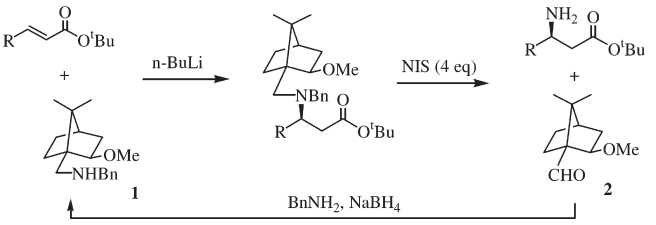
α,β-unsaturated carbonyls with (+)-bornyl-10-mercapto alcohol to afford optically active β-mercapto alcohols with three contiguous chiral centers.[8] Encouraged by the successful results in the reaction, the asymmetric Michael addition of α,β-unsaturated esters with a chiral amine, *N*-benzyl-2(*R*)-methoxy-(+)-10-bornylamine (**1**), was investigated.[9] In good contrast with the tandem Michael−Meerwein−Prondorff−Verley (MPV) reduction, the Michael addition using **1** as a nucleophile promoted no further reaction; however, the Michael addition with **1** generated an enolate, which could still be reacted with electrophiles. Thus, we tried to apply the Michael addition of α,β-unsaturated esters with **1** to the tandem asymmetric Michael−aldol reaction, double Michael reaction, and double Michael−aldol reaction.

Both phenethyl and benzyl groups on the amino group employed in Davies' tandem reactions[2,10] were cleavable with relative ease under the hydrogenolysis condition;[11] however, disposal of the chiral auxiliary reduced the utility in terms of atom economy. Meanwhile, the chiral bornyl and benzyl groups on the amino groups, which were incorporated in the step of the Michael addition of **1**, could be easily cleaved by treatment with NIS.[12] Moreover, the chiral amine **1** can be regenerated by the reductive amination of bornyl aldehyde **2**, which resulted in oxidative cleavage of the C−N bonds with NIS (Scheme 1).[9] In addition, no requirement of hydrogenation to cleave the benzyl group or of the products could increase the availability of our method, which we report here.

Results and Discussion

Initially, *tert*-butyl β-isopropylacrylate (**3a**) and *tert*-butyl cinnamate (**3b**) were chosen as the substrates of the Michael addition of **1**, and the enolate intermediate was reacted with benzaldehyde (**4a**) to complete the asymmetric Michael−aldol reaction (Scheme 2).

SCHEME 1. Michael Addition of α,β-Unsaturated Esters with the Chiral Amine 1



Namely, *n*-butyllithium (1.5 equiv) was added to a solution of **1** in tetrahydrofuran (THF) at −50 °C to prepare the corresponding amide, to which either **3a** or **3b** (1.0 equiv) was added to complete the Michael addition. Successively, **4a** (3.0 equiv) was added dropwise to the reaction mixture while maintaining the temperature. As a result, in spite that diastereomers **5a**, **6a**, and **6a′** were obtained with the ratio of 1:1:1.3 in the reaction of **3a**, **5b** and its isomers **6b** were obtained with high diastereoselectivity (89:11) in good yield accompanied by a small amount of the nonaldol product **7b** in the reaction of **3b** (Scheme 2) .

We investigated several conditions, in which substrates **3c**−**e**, having a substitute on the aromatic ring of **3b**, were chosen as the Michael acceptor. As a result, aldol products **5c**−**e** were afforded in good yield. Next, several aliphatic and aromatic aldehydes **4b**−**g** were subjected to the aldol reaction, and products **5f**−**k** were obtained in as good of yields as **5b**−**e** (Table 1).

Stereochemistry of the major product **5b** was determined by X-ray diffraction analysis after debenzylation on the amino group with formic acid in the presence of Pd/C, followed by protection of the secondary hydroxyl group with the Boc group, to afford **8b** (see Table 3). In addition, the stereochemistry of **5a** and **6a** was directly determined by X-ray diffraction analysis.

Regarding the transition state of the aldol reaction to afford the major products, it was speculated as shown in Scheme 3. Namely, lithium ion coordinates the carbonyl oxygen of the ester group to form a six-membered transition state, where the *Z*-enolate intermediate is generated from the *s-cis* conformer of α,β-unsaturated ester.[13] The aldehyde would approach preferentially from the bottom to the upper face of the enolate due to steric hindrance caused by the presence of the *N*-benzyl group. Addition of the aldehyde, the *Re* face of which should be preferentially attacked to that of the *Si*-face, affords the major product **5b**. Higher selectivity in the reaction using **3b** than **3a** as the Michael acceptor could be attributed to the $\pi-\pi$ interaction between the phenyl groups of **1** and the Michael acceptor, which stabilize the *Z*-enolate intermediate (**A**, Scheme 3).

Next, double Michael addition was applied to a substrate with a pair of α,β-unsaturated esters in its molecule, i.e., di-*tert*-butyl nona-2,7-diene-1,9-diate (**9a**). When the reaction was achieved at −50 °C, the desired product (**10a**) was obtained in high yield (91%) with high diastereoselectivity

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SCHEME 2. Tandem Michael−Aldol Reaction Using 3a,b and Benzaldehyde (4a)

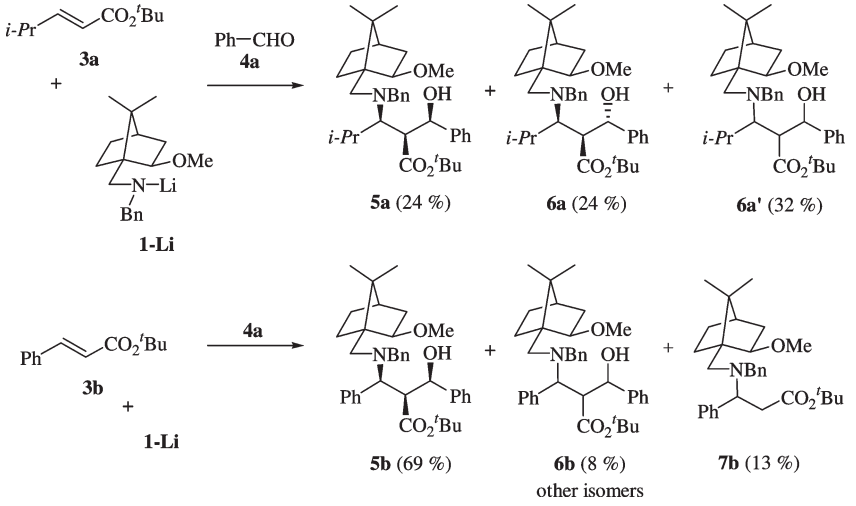
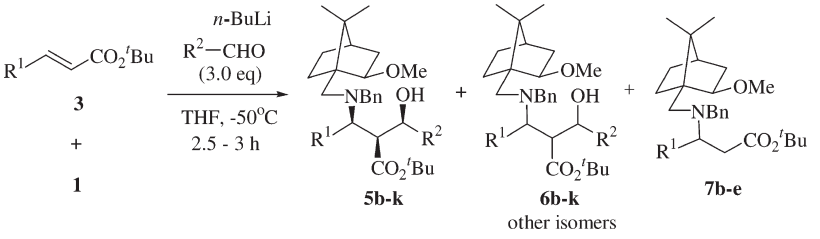


TABLE 1. Tandem Michael−Aldol Reaction



entry	R^1		R^2		Products (%)[a]		
1	Ph	(**3b**)	Ph	(**4a**)	**5b** (71)	**6b** (9)	**7b** (9)
2	4-Cl-Ph	(**3c**)	Ph	(**4a**)	**5c** (57)	**6c** (12)	**7c** (4)
3	4-Me-Ph	(**3d**)	Ph	(**4a**)	**5d** (72)	**6d** (10)	**7d** (11)
4	4-MeO-Ph	(**3e**)	Ph	(**4a**)	**5e** (61)	**6e** (8)	**7e** (17)
5	Ph	(**3b**)	4-Cl-Ph	(**4b**)	**5f** (51)	**6f** (9)	**7b** (15)
6	Ph	(**3b**)	4-Me-Ph	(**4c**)	**5g** (62)	**6g** (11)	**7b** (14)
7	Ph	(**3b**)	4-MeO-Ph	(**4d**)	**5h** (77)	**6h** (10)	**7b** (1)
8	Ph	(**3b**)	*i*-Pr	(**4e**)	**5i** (84)	**6i** (9)	**7b** (2)
9	Ph	(**3b**)	*c*-Hex	(**4f**)	**5j** (71)	**6j** (16)	**7b** (17)
10	Ph	(**3b**)	*n*-Pen	(**4g**)	**5k** (81)	**6k** (12)	**7b** (4)

[a]Isolated yields.

(93:7) (Table 2, entry 1). Moreover, the double Michael reaction was applied to the formation of trisubstituted cyclopentane, where di-*tert*-butyl 2,6-octadien-1,8-diate (**9b**) was chosen as the Michael acceptor. The desired product **10b** was isolated in excellent yield (96%) with high diastereoselectivity (89: 11) (Table 2, entry 2). The stereochemistry of **10a** and **10b** was confirmed by comparison with the ^{13}C NMR data in the literature[14] after cleaving the chiral auxiliary and the benzyl group with NIS (4.0 equiv). Furthermore, the addition of aldehydes (**4a**−**f**) to the double Michael adduct in situ was attempted to investigate the possibility of constructing five contiguous chiral centers. Fortunately, the desired product **11a** was afforded in good yield (71%) with satisfactory diastereoselectivity (84:16) when benzaldehyde (**4a**) was added to the double Michael intermediate prepared from **1** and **9a** (Table 2, entry 3).

However, the double Michael addition−aldol reaction, where the enolate anion of **10b** generated in the double Michael addition of **1** and **9b** was reacted with benzaldehyde (**4a**), gave an unsatisfactory result in terms of stereoselectivity. Reactions with other aromatic aldehydes **4b**−**d** provided **11b**−**d** in good yield with moderate stereoselectivity (Table 2, entry 3−6).

Although low selectivities were observed in the reactions with an aliphatic aldehyde **4e**−**f**, it should be emphasized that one isomer among 32 possible isomers was afforded in 40−42% (Table 2, entries 7 and 8).

The stereochemistry of the major product of **11a** was determined by X-ray diffraction analysis after deriving to **12** as well as **5b**. The stereochemistries of **11b**−**f** were proposed by the comparison of their ^1H NMR spectra with that of **11a**.

(14) The ^{13}C NMR spectrum and the value of $[\alpha]_D$ of the primary amine obtained by the cleavage of the 2-methoxy-10-bornyl group and benzyl group of **10b** with NIS (4 equiv) completely coincided with those reported by Davies. Meanwhile, the primary amine derived from **10a** in the same way provided a partially different ^{13}C NMR spectrum from those reported by Davies. Since the primary amines obtained from **10a** were the enantiomers of that synthesized by Davies, the values of those amines showed opposite signs but showed almost the same values. See ref 2.

SCHEME 3. Plausible Transition State of the Michael−Aldol Reaction

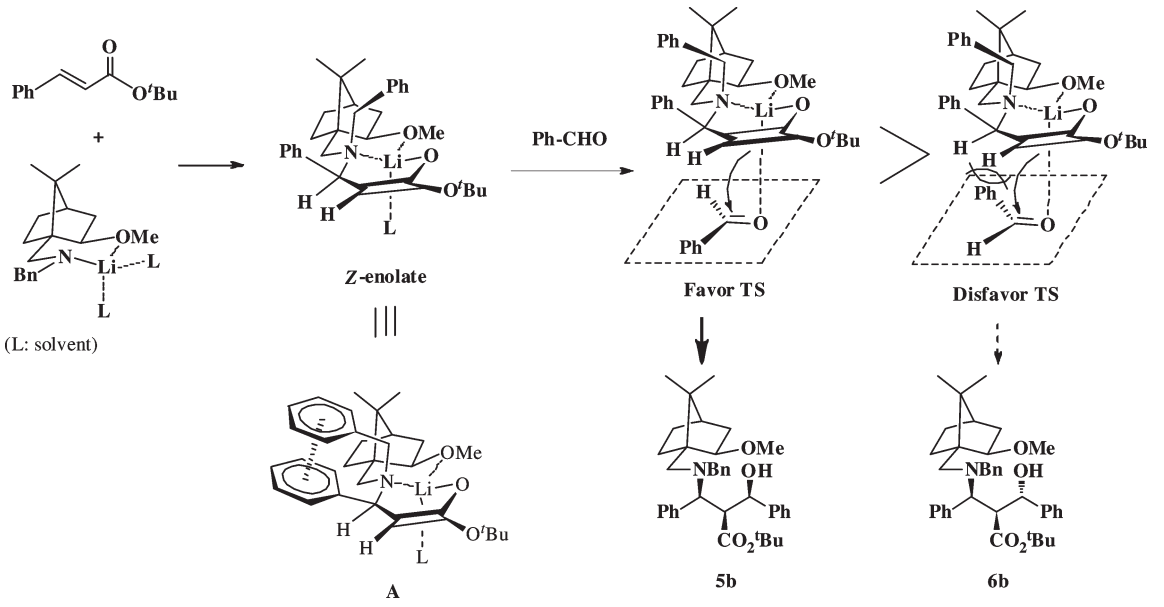
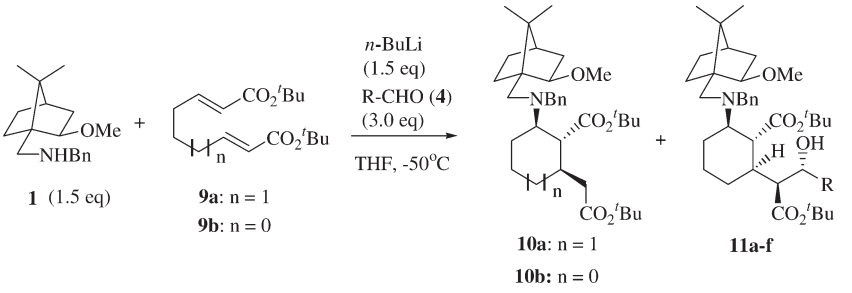


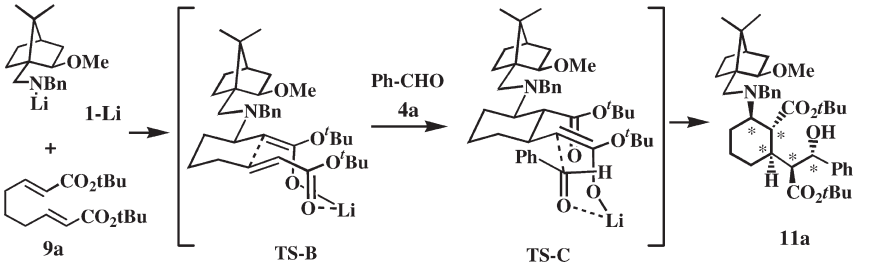
TABLE 2. Intramolecular Double Michael Addition and Tandem Double Michael−Aldol Reaction



				time (h)				
entry	substrate	R		Michael	aldol	major product	yield[a] (%)	minor products[a] (%)
1	**9a**	none of aldehyde		2.0		**10a**	85	6
2	**9b**	none of aldehyde		2.0		**10b**	85	11
3	**9a**	Ph	(**4a**)	0.5	2.0	**11a**	60	11
4	**9a**	4-Cl-Ph	(**4b**)	0.5	2.0	**11b**	55	22
5	**9a**	4-Me-Ph	(**4c**)	0.5	2.0	**11c**	67	17
6	**9a**	4-MeO-Ph	(**4d**)	0.5	2.0	**11d**	57	26
7	**9a**	*i*-Pr	(**4e**)	0.5	2.0	**11e**	40	46
8	**9a**	*c*-Hex	(**4f**)	0.5	2.0	**11f**	42	45

[a]Isolated yields.

SCHEME 4. Plausible Transition State of the Double Michael−Aldol Reaction Affording 11a



A plausible transition state could be proposed, as shown in Scheme 4, i.e., the intramolecular Michael addition would advance via TS-B, as reported by Davies,[2b] and the subsequent aldol reaction with **4a** would proceed via TS-C to afford **11a**.

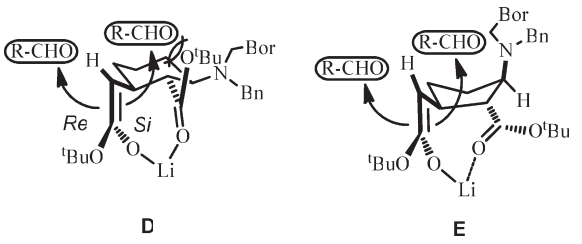
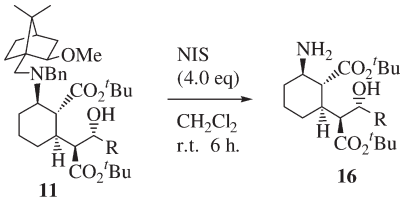


FIGURE 1. Comparison of the enolate intermediates in the reactions using **9a** (D) and **9b** (E) as substrates.

A similar transition state would rationalize the low selectivity of the tandem reaction using **9b** (Figure 1). Standing vertical in enolate **D** to avoid steric hindrance with the equatorial orientated-amino group on the cyclohexane ring, the *tert*-butoxy group of the nonenolated ester moiety could effectively inhibit the access of the aldehyde from the *Si* face. Meanwhile, the enolate generated by the Michael addition of **1** and **9b** formed enolate **E**, in which the *tert*-butoxy group of the nonenolated ester moiety would lie horizontally due to steric repulsion with the bulky amino group. Both faces of enolate **E** are exposed to allow the approach of the aldehyde. Thus, satisfactory stereoselectivity of the product was not observed in the double Michael−aldol reaction using **1**, **9b**, and **4a**.

Finally, conditions for removal of the chiral auxiliary were scrutinized. We reported that the 2-methoxy-10-bornyl and the benzyl groups on the amino group can be removed by oxidative cleavage using *N*-iodosuccinimide (NIS) and, if necessary, successive treatment with *O*-methylhydroxylamine.[9,12] Thus, the Michael−aldol product **5b** was first treated with NIS (4 equiv) in dichloromethane; however, the desired β-amino ester was not obtained due to the neighboring group participation of the hydroxyl group in **5b**. Next, the treatment with NIS was performed after protection of the hydroxyl group with acetyl, Boc, and silyl groups (Table 3). Although O→N migration of the acetyl group was observed during the reaction (Table 3, entry 1), Boc and TES groups remained on the hydroxyl group (Table 3, entries 2 and 3). Cleavage of the 2-methoxy-10-bornyl and benzyl groups from amino group proceeded in satisfactory yield and was a practical deprotection of the Boc compound.

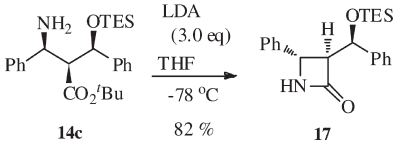
TABLE 4. Cleavage of C−N Bonds of 11 Utilizing NIS



entry	substrate	R	yield (%)
1	**11a**	Ph	77[a]
2	**11b**	4-Cl-Ph	78
3	**11c**	4-Me-Ph	76
4	**11d**	4-MeO-Ph	72

[a]Bornyl aldehyde **2** was recoverd in 74% yield.

SCHEME 5. Preparation of the β-Lactam Derivative from 14c



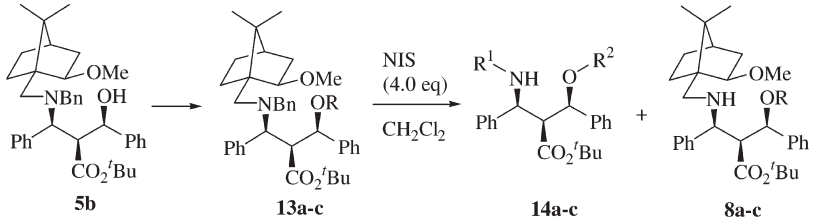
Interestingly, the 2-methoxy-10-bornyl and the benzyl group of **11a** and **11b−d** could be cleaved with NIS (4 equiv) in satisfactory yield without protection of the hydroxyl group generated in the aldol reaction (Table 4).

Finally, as an example of the application of the tandem Michael−aldol reaction, β-lactam **17** was prepared from amino ester **14c** by treating with LDA (Scheme 5).

Conclusion

In conclusion, we have developed the stereocontrolled one-pot synthesis of three or five contiguous chiral centers using tandem asymmetric Michael−aldol, intramolecular double-Michael, and double Michael−aldol reactions initiated by the addition of chiral amide **1** to α,β-unsaturated esters. This is the first method of the amination that can build up the five contiguous chiral centers in one pot. The method was shown to be applicable for the synthesis of β-lactam antibiotics.

TABLE 3. Cleavage of C−N Bonds of 5b Utilizing NIS



entry	R[a]	**13a−c** yield (%)	R^1	R^2	**14a−c** yield (%)	**8a−c** yield (%)
1	Ac	96	Ac	H	96[b]	
2	Boc	93	H	Boc	81	
3	TES	100	H	TES	42	40[c]

[a]Ac = acetyl, Boc = *tert*-butoxycarbonyl, TES = triethylsilyl. [b]Bornyl aldehyde **2** was recoverd in 95%yield. [c]**8c** could be converted to **14c** in 81% yield by treating with NIS (2.0 equiv).

Experimental Section

A typical procedure for the tandem Michael−aldol reaction was shown by representing the reaction of **1** and **3b**. The major products (**5b**−**k**) were isolated as a single diastereomer by employing silica gel column chromatography or recycle HPLC.

(2*S*,3*S*)-*tert*-Butyl 2-[(*R*)-Hydroxy(phenyl)methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-3-phenylpropanoate (5b). *n*-Buthyllithium (2.6 M in hexane solution, 1.1 mL, 2.91 mmol) was added dropwise to a solution of chiral amine **1** (796 mg, 2.91 mmol) in THF (20 mL) at −50 °C, and the solution was stirred for 5 min under an argon atmosphere. A solution of α,β-unsaturated ester **3b** (396.4 mg, 1.94 mmol) in THF (10 mL) was added dropwise to the lithium amide solution at the same temperature, and the mixture was stirred for 0.5 h. Then, benzaldehyde (591 μL, 5.82 mmol) was added dropwise to the solution at the same temperature, and the mixture was stirred for 2 h. The reaction mixture was quenched with a saturated aqueous solution of sodium hydrogen carbonate and extracted with diethyl ether. The organic layer was washed with brine, dried over anhydrous sodium sulfate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate = 80/1) to afford **5b** as a single diastereomer (807 mg, 71%) as well as a mixture of minor diastereomers (102 mg, 9%): colorless oil; $[\alpha]^{22}_{D} = -64.3$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42−7.17 (m, 15H), 4.53 (d, *J* = 11.7 Hz, 1H), 4.49 (dd, *J* = 2.6, 10.8 Hz, 1H), 4.03 (d, *J* = 10.8 Hz, 1H), 3.92 (d, A part of AB, J_{AB} = 13.7 Hz, 1H), 3.61 (dd, *J* = 2.6, 11.7 Hz, 1H), 3.40 (d, B part of AB, J_{AB} = 13.7 Hz, 1H), 3.21 (d, A part of AB, J_{AB} = 14.3 Hz, 1H), 3.23−3.19 (br, 1H), 2.95 (s, 3H), 2.24 (d, B part of AB, J_{AB} = 14.3 Hz, 1H), 1.69−1.55 (m, 4H), 1.43 (dd, *J* = 7.3, 12.6 Hz, 1H), 1.26−1.16 (m, 1H), 1.24 (s, 9H), 0.94−0.90 (m, 1H), 0.86 (s, 3H), 0.81 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.6, 142.6, 140.4, 136.5, 129.8, 129.6 (2C), 128.1 (2C), 127.9 (2C), 127.7 (2C), 127.3 (2C), 126.8, 126.7, 125.3 (2C), 84.9, 82.0, 71.6, 64.5, 57.5, 54.5, 53.6, 53.0, 47.6, 46.3, 45.0, 37.3, 29.7, 28.0 (3C), 27.3, 20.9, 20.3; IR ($CHCl_3$) 3479, 2934, 1695, 1603, 1452, 1369, 1150 cm^{-1}; MS (20 eV) *m*/*z*: 583 (M^+, 2), 362 (100), 272 (13), 242 (10), 204 (12), 148 (63), 131 (17), 106 (99); HRMS calcd for $C_{38}H_{49}NO_4$ (M^+) 583.3661, found 583.3653.

***tert*-Butyl 2-[Hydroxy(phenyl)methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-4-methylpentanoate (5a, 6a).** ^{1}H NMR spectra of **6a′**, **5a** (major isomer and minor isomer-1) were broad. Therefore compound data of **6a′**, **5a** (major isomer and minor isomer-1) were collected as acetyl form of hydroxyl group (**6a′-Ac, 5a-Ac**).

6a′-Ac: major isomer: colorless oil; $[\alpha]^{20}_{D} = +11.1$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37−7.27 (m, 5H), 7.09 (m, 3H), 6.81 (m, 2H), 6.09 (d, *J* = 9.5 Hz, 1H), 3.69 (d, A part of AB, J_{AB} = 14.3 Hz, 1H), 3.44 (dd, *J* = 2.7, 9.5 Hz, 1H), 3.24 (br d, *J* = 3.8 Hz, 1H), 3.12 (br, B part of AB, 1H), 3.04 (s, 3H), 2.97 (d, A part of AB, J_{AB} = 13.6 Hz, 1H), 2.32 (br, 1H), 2.28 (d, B part of AB, J_{AB} = 13.6 Hz, 1H), 2.12−2.04 (m, 1H), 1.99 (s, 3H), 1.72−1.40 (m, 6H), 1.45 (s, 9H), 1.13 (d, *J* = 6.2 Hz, 3H), 0.97−0.93 (m, 1H), 0.96 (d, *J* = 6.2 Hz, 3H), 0.93 (s, 3H), 0.74 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.8, 169.5, 140.5, 139.2, 129.4 (2C), 128.6 (2C), 128.1, 127.7 (2C), 127.5 (2C), 126.2, 85.4, 80.6, 76.5, 65.1, 55.6, 54.6, 53.1, 52.2, 48.0, 47.8, 45.1, 37.4, 31.0, 29.6, 28.0 (3C), 27.3, 22.4 (2C), 21.2, 20.9, 20.5; IR ($CHCl_3$) 2953, 2936, 1734, 1456, 1369, 1240, 1146 cm^{-1}; MS (20 eV) *m*/*z* 591 (M^+, 0.2), 548 (90), 327 (100), 284 (61), 204 (38), 148 (81); HRMS calcd for $C_{37}H_{53}NO_5$ (M^+) 591.3923, found 591.3925.

(2*S*,3*R*)-*tert*-Butyl 2-[(*R*)-acetoxy(phenyl)methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-4-methylpentanoate (5a-Ac: minor isomer-1): colorless oil; $[\alpha]^{19}_{D} = +16.2$ (*c* 0.9, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (d, *J* = 7.4 Hz, 2H), 7.32−7.20 (m, 8H), 5.97 (d, *J* = 5.1 Hz, 1H), 3.68 (s, 2H), 3.39 (dd, *J* = 3.4, 7.2 Hz, 1H), 3.30 (dd, *J* = 5.1, 9.0 Hz, 1H), 3.25 (d, A part of AB, J_{AB} = 13.4 Hz, 1H), 3.17 (dd, *J* = 4.6, 9.0 Hz, 1H), 3.07 (s, 3H), 2.38 (d, B part of AB, J_{AB} = 13.4 Hz, 1H), 2.07 (s, 3H), 1.76−1.53 (m, 6H), 1.35−1.19 (m, 1H), 1.24 (s, 9H), 1.04−1.00 (m, 1H), 0.94 (d, *J* = 7.1 Hz, 3H), 0.92 (s, 3H), 0.81 (s, 3H), 0.62 (d, *J* = 5.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.0, 170.1, 141.1, 138.5, 130.8 (2C), 128.2 (2C), 127.6 (3C), 126.6, 126.4 (2C), 86.1, 80.6, 74.2, 60.7, 56.3, 54.7, 53.4, 51.6, 48.0, 46.9, 45.1, 37.6, 30.2, 29.4, 27.6 (3C), 27.3, 21.1, 21.1, 21.0, 20.4, 18.8; IR ($CHCl_3$) 2955, 1732, 1719, 1454, 1369, 1151 cm^{-1}; MS (20 eV) *m*/*z* 591 (M^+, 0.2), 548 (55), 327 (100), 284 (45), 204 (20), 148 (43); HRMS calcd for $C_{37}H_{53}NO_5$ (M^+) 591.3923, found 591.3919.

(2*S*,3*R*)-*tert*-Butyl 2-[(*S*)-hydroxy(phenyl)methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-4-methylpentanoate (6a: minor isomer-2): colorless crystal; mp 196−198 °C (diethyl ether); $[\alpha]^{22}_{D} = +49.2$ (*c* 0.8, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (br d, *J* = 8.2 Hz, 2H), 7.37−7.20 (m, 8H), 5.30 (dd, *J* = 2.0, 10.2 Hz, 1H), 4.63 (br, 1H), 3.88 (s, 2H), 3.43 (d, A part of AB, J_{AB} = 14.8 Hz, 1H), 3.42 (dd, *J* = 3.1, 7.3 Hz, 1H), 3.28 (dd,, *J* = 3.5, 10.3 Hz, 1H), 3.21 (s, 3H), 3.05 (dd, *J* = 3.5, 9.9 Hz, 1H), 2.62 (d, B part of AB, J_{AB} = 14.8 Hz, 1H), 2.31−2.22 (m, 1H), 1.75 (dq, *J* = 3.3, 12.8 Hz, 1H), 1.55 (t, *J* = 4.2 Hz, 1H), 1.47 (dd, *J* = 7.3, 12.8 Hz, 1H), 1.37−1.30 (m, 1H), 1.27 (d, *J* = 6.6 Hz, 3H), 1.19 (d, *J* = 6.2 Hz, 3H), 1.09 (s, 9H), 0.97−0.87 (m, 1H), 0.92 (s, 3H), 0.82−0.76 (m, 1H), 0.56 (s, 3H), 0.49 (br, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.7, 142.9, 141.2, 130.7 (2C), 128.0 (2C), 127.8 (2C), 127.7 (2C), 127.6, 126.7, 85.7, 80.3, 73.2, 65.5, 56.5, 55.9, 54.2, 53.4, 48.2, 47.7, 45.4, 37.1, 30.3, 29.9, 27.5 (3C), 26.9, 23.1, 22.5, 20.6, 20.4; IR ($CHCl_3$) 3396, 2951, 1715, 1603, 1456, 1367, 1148 cm^{-1}; MS (20 eV) *m*/*z* 549 (M^+, 0.1), 344 (22), 328 (44), 106 (92), 91 (100); HRMS calcd for $C_{35}H_{51}NO_4$ (M^+) 549.3818, found 549.3824. Anal. Calcd for $C_{35}H_{51}NO_4$: C, 76.46; H, 9.35; N, 2.55. Found: C, 76.19; H, 9.19; N, 2.54.

(2*S*,3*S*)-*tert*-Butyl 3-(4-chlorophenyl)-2-[(*R*)-hydroxy(phenyl)-methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]propanoate (5c): colorless oil; $[\alpha]^{20}_{D} = -66.0$ (*c* 0.6, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39−7.18 (m, 14H), 4.50 (d, *J* = 11.5 Hz, 1H), 4.44 (dd, *J* = 2.4, 11.0 Hz, 1H), 4.00 (d, *J* = 11.0 Hz, 1H), 3.88 (d, A part of AB, J_{AB} = 13.9 Hz, 1H), 3.55 (dd, *J* = 2.6, 11.5 Hz, 1H), 3.40 (d, B part of AB, J_{AB} = 13.9 Hz, 1H), 3.23 (d, A part of AB, J_{AB} = 14.3 Hz, 1H), 3.26−3.21 (br, 1H), 2.99 (s, 3H), 2.18 (d, B part of AB, J_{AB} = 14.3 Hz, 1H), 1.72−1.66 (m, 1H), 1.62−1.49 (m, 3H), 1.45 (dd, *J* = 7.3, 12.6 Hz, 1H), 1.24 (s, 9H), 1.21−1.15 (m, 1H), 0.96−0.91 (m, 1H), 0.87 (s, 3H), 0.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.3, 142.2, 140.1, 135.3, 133.0, 131.0 (2C), 129.5 (2C), 128.3 (2C), 127.9 (2C), 127.8 (2C), 126.9, 126.8, 125.3 (2C), 84.9, 82.2, 71.7, 63.7, 57.6, 54.5, 53.5, 53.0, 47.6, 46.1, 45.0, 37.2, 29.7, 27.9 (3C), 27.3, 20.9, 20.3; IR ($CHCl_3$) 3690, 3020, 2936, 1697, 1603, 1495 cm^{-1}; MS (20 eV) *m*/*z* 617 (M^+, 0.6), 396 (100), 272 (6), 182 (11), 106 (32); HRMS calcd for $C_{38}H_{48}ClNO_4$ (M^+) 617.3272, found 617.3265.

(2*S*,3*S*)-*tert*-Butyl 2-[(*R*)-hydroxy(phenyl)methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-3-*p*-tolylpropanoate (5d): colorless oil; $[\alpha]^{20}_{D} = -59.9$ (*c* 0.9, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 7.6 Hz, 2H), 7.31−7.16 (m, 12H), 4.49 (d, *J* = 11.7 Hz, 1H), 4.49 (dd, *J* = 2.6, 10.8 Hz, 1H), 3.99 (d, *J* = 10.8 Hz, 1H), 3.92 (d, A part of AB, J_{AB} = 13.7 Hz, 1H), 3.58 (dd, *J* = 2.6, 11.7 Hz, 1H), 3.35 (d, B part of AB, J_{AB} = 13.7 Hz, 1H), 3.20−3.16 (br, 1H), 3.18 (d, A part of AB, J_{AB} = 15.0 Hz, 1H), 2.92 (s, 3H), 2.37 (s, 3H), 2.22 (d, B part of AB, J_{AB} = 15.0 Hz, 1H), 1.68−1.55 (m, 4H), 1.43 (dd, *J* = 7.4, 12.5 Hz, 1H), 1.23 (s, 9H), 1.25−1.18 (m, 1H), 0.95−0.90 (m, 1H), 0.86 (s, 3H), 0.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.6, 142.6, 140.4, 136.8, 133.1, 129.8 (2C), 129.6 (2C), 128.8 (2C), 127.8 (2C), 127.6 (2C), 126.7, 126.6, 125.3 (2C), 84.9, 81.9, 71.6, 64.3, 57.6, 54.4, 53.9, 53.0, 47.6, 46.4, 45.0, 37.3, 29.7, 28.0 (3C), 27.4, 21.1, 20.9, 20.3; IR ($CHCl_3$) 3690, 2934, 1695, 1603, 1452, 1367 cm^{-1}; MS (20 eV) *m*/*z* 597 (M^+, 0.6), 376 (100), 162 (9), 106 (19); HRMS calcd for $C_{39}H_{51}NO_4$ (M^+) 597.3818, found 597.3810.

(2*S*,3*S*)-*tert*-Butyl 2-[(*R*)-hydroxy(phenyl)methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-3-(4-methoxyphenyl)propanoate (5e): colorless oil; $[\alpha]^{14}_{D} = -61.5$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, J = 7.6 Hz, 2H), 7.31−7.16 (m, 10H), 6.94 (d, J = 8.8 Hz, 2H), 4.49 (d, J = 11.7 Hz, 1H), 4.48 (dd, J = 2.6, 10.8 Hz, 1H), 4.00 (d, J = 10.8 Hz, 1H), 3.91 (d, A part of AB, J_{AB} = 13.7 Hz, 1H), 3.83 (s, 3H), 3.56 (dd, J = 2.6, 11.7 Hz, 1H), 3.36 (d, B part of AB, J_{AB} = 13.7 Hz, 1H), 3.21−3.16 (br, 1H), 3.19 (d, A part of AB, J_{AB} = 16.7 Hz, 1H), 2.94 (s, 3H), 2.20 (d, B part of AB, J_{AB} = 16.7 Hz, 1H), 1.69−1.56 (m, 4H), 1.43 (dd, J = 7.4, 12.5 Hz, 1H), 1.23 (s, 9H), 1.22−1.18 (m, 1H), 0.96−0.90 (m, 1H), 0.86 (s, 3H), 0.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.6, 158.7, 142.6, 140.4, 130.9 (2C), 129.6 (2C), 128.4, 127.8 (2C), 127.7 (2C), 126.7, 126.6, 125.3 (2C), 113.5 (2C), 84.9, 81.9, 71.7, 63.9, 57.6, 55.2, 54.5, 54.0, 53.0, 47.5, 46.3, 45.0, 37.3, 29.7, 28.0 (3C), 27.3, 20.9, 20.3; IR ($CHCl_3$) 3690, 3034, 2936, 1695, 1609, 1512, 1367 cm^{-1}; MS (20 eV) m/z 613 (M^+, 0.3), 392 (100), 234 (19), 178 (65), 106 (88); HRMS calcd for $C_{39}H_{51}NO_5$ (M^+) 613.3767, found 613.3764.

(2*S*,3*S*)-*tert*-Butyl 2-[(*R*)-(4-chlorophenyl)(hydroxy)methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-3-phenylpropanoate (5f): colorless oil; $[\alpha]^{21}_{D} = -55.6$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42−7.19 (m, 14H), 4.51 (d, J = 11.7 Hz, 1H), 4.45 (dd, J = 2.6, 10.6 Hz, 1H), 4.07 (d, J = 10.6 Hz, 1H), 3.90 (d, A part of AB, J_{AB} = 13.7 Hz, 1H), 3.56 (dd, J = 2.6, 11.7 Hz, 1H), 3.41 (d, B part of AB, J_{AB} = 13.7 Hz, 1H), 3.22 (d, A part of AB, J_{AB} = 15.0 Hz, 1H), 3.25−3.20 (br, 1H), 2.96 (s, 3H), 2.23 (d, B part of AB, J_{AB} = 15.0 Hz, 1H), 1.71−1.51 (m, 4H), 1.44 (dd, J = 7.4, 12.7 Hz, 1H), 1.28 (s, 9H), 1.26−1.12 (m, 1H), 0.95−0.88 (m, 1H), 0.86 (s, 3H), 0.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.4, 141.2, 140.2, 136.4, 132.5, 129.7 (2C), 129.6 (2C), 128.2 (2C), 128.0 (2C), 127.7 (2C), 127.4, 126.8 (2C), 126.7, 84.9, 82.3, 71.2, 64.4, 57.5, 54.5, 53.4, 53.0, 47.6, 46.3, 45.0, 37.2, 29.7, 28.0 (3C), 27.3, 20.9, 20.3; IR ($CHCl_3$) 3692, 3032, 2936, 1693, 1601, 1491, 1369 cm^{-1}; MS (20 eV) m/z 617 (M^+, 0.8), 396 (100), 272 (7), 182 (10), 148 (29), 140 (18), 106 (45); HRMS calcd for $C_{38}H_{48}ClNO_4$ (M^+) 617.3272, found 617.3263.

(2*S*,3*S*)-*tert*-Butyl 2-[(*R*)-hydroxy(*p*-tolyl)methyl]-3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino-3-phenylpropanoate (5g): colorless oil; $[\alpha]^{24}_{D} = -61.5$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42−7.21 (m, 10H), 7.14 (d, J = 7.9 Hz, 2H), 7.07 (d, J = 8.1 Hz, 2H), 4.52 (d, J = 11.5 Hz, 1H), 4.45 (dd, J = 1.8, 10.8 Hz, 1H), 4.00 (d, J = 10.8 Hz, 1H), 3.92 (d, A part of AB, J_{AB} = 13.9 Hz, 1H), 3.59 (dd, J = 2.7, 11.7 Hz, 1H), 3.40 (d, B part of AB, J_{AB} = 13.9 Hz, 1H), 3.22−3.18 (br, 1H), 3.20 (d, A part of AB, J_{AB} = 14.8 Hz, 1H), 2.95 (s, 3H), 2.30 (s, 3H), 2.24 (d, B part of AB, J_{AB} = 14.8 Hz, 1H), 1.69−1.52 (m, 4H), 1.43 (dd, J = 7.3, 12.6 Hz, 1H), 1.26 (s, 9H), 1.20−1.16 (m, 1H), 0.94−0.90 (m, 1H), 0.86 (s, 3H), 0.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.6, 140.4, 139.5, 136.6, 136.2, 129.8 (2C), 129.6 (2C), 128.5 (2C), 128.1 (2C), 127.7 (2C), 127.2, 126.6, 125.2 (2C), 85.0, 81.9, 71.5, 64.4, 57.5, 54.5, 53.5, 53.0, 47.6, 46.2, 45.1, 37.3, 29.7, 28.0 (3C), 27.3, 21.0, 20.9, 20.3; IR ($CHCl_3$) 3692, 3028, 2936, 1695, 1603, 1454, 1367, 1150 cm^{-1}; MS (20 eV) m/z 597 (M^+, 1), 362 (100), 162 (31), 148 (70), 120 (67), 106 (98), 91 (35); HRMS calcd for $C_{39}H_{51}NO_4$ (M^+) 597.3818, found 597.3810.

(2*S*,3*S*)-*tert*-Butyl 3-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-2-[(*R*)-(4-methoxyphenyl)(hydroxy)methyl]-3-phenylpropanoate (5h): colorless oil; $[\alpha]^{21}_{D} = -63.2$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41−7.20 (m, 10H), 7.18 (d, J = 8.8 Hz, 2H), 6.82 (d, J = 8.8 Hz, 2H), 4.52 (d, J = 11.7 Hz, 1H), 4.44 (dd, J = 2.4, 10.8 Hz, 1H), 4.00 (d, J = 10.8 Hz, 1H), 3.92 (d, A part of AB, J_{AB} = 13.9 Hz, 1H), 3.77 (s, 3H), 3.58 (dd, J = 2.6, 11.7 Hz, 1H), 3.40 (d, B part of AB, J_{AB} = 13.9 Hz, 1H), 3.22−3.18 (br, 1H), 3.20 (d, A part of AB, J_{AB} = 15.2 Hz, 1H), 2.95 (s, 3H), 2.25 (d, B part of AB, J_{AB} = 15.2 Hz, 1H), 1.67 (dq, J = 2.9, 12.5 Hz, 1H), 1.61−1.56 (m, 3H), 1.43 (dd, J = 7.5, 12.6 Hz, 1H), 1.28 (s, 9H), 1.20−1.13 (m, 1H), 0.94−0.90 (m, 1H), 0.86 (s, 3H), 0.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 174.7, 158.5, 140.4, 136.6, 134.8, 129.8 (2C), 129.6 (2C), 128.1 (2C), 127.7 (2C), 127.2, 126.6, 126.4 (2C), 113.3 (2C), 85.0, 82.0, 71.3, 64.4, 57.5, 55.3, 54.5, 53.6, 53.0, 47.6, 46.2, 45.0, 37.3, 29.7, 28.0 (3C), 27.3, 20.9, 20.3; IR ($CHCl_3$) 3690, 2936, 1695, 1603, 1512, 1367, 1150 cm^{-1}; MS (20 eV) m/z 613 (M^+, 1), 362 (100), 272 (11), 106 (16); HRMS calcd for $C_{39}H_{51}NO_5$ (M^+) 613.3767, found 613.3760.

(2*S*,3*S*)-*tert*-Butyl 3-hydroxy-2-[(*S*)-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino](phenyl)methyl]-4-methylpentanoate (5i): colorless oil; $[\alpha]^{21}_{D} = -60.2$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36−7.18 (m, 10H), 4.48 (d, J = 11.7 Hz, 1H), 3.91 (d, A part of AB, J_{AB} = 13.9 Hz, 1H), 3.44 (dd, J = 2.2, 11.5 Hz, 1H), 3.31 (d, B part of AB, J_{AB} = 13.9 Hz, 1H), 3.17 (br d, J = 4.0 Hz, 1H), 3.10 (d, A part of AB, J_{AB} = 14.5 Hz, 1H), 3.06 (d, J = 11.0 Hz, 1H), 2.91 (s, 3H), 2.71 (dt, J = 2.2, 11.0 Hz, 1H), 2.24 (d, B part of AB, J_{AB} = 14.5 Hz, 1H), 1.69−1.53 (m, 5H), 1.63 (s, 9H), 1.51−1.44 (m, 1H), 1.43 (dd, J = 7.3, 12.5 Hz, 1H), 1.18 (m, 1H), 0.91 (d, J = 6.6 Hz, 3H), 0.86 (s, 3H), 0.84 (s, 3H), 0.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 140.6, 136.7, 129.7 (2C), 129.7 (2C), 128.0 (2C), 127.6 (2C), 127.0, 126.5, 85.2, 82.0, 76.7, 64.8, 57.1, 54.5, 53.0, 49.0, 47.6, 46.6, 45.0, 37.3, 33.5, 29.8, 28.4 (3C), 27.3, 20.9, 20.3, 20.2, 19.1; IR ($CHCl_3$) 3690, 2936, 1692, 1601, 1454, 1367, 1150 cm^{-1}; MS (20 eV) m/z 549 (M^+, 0.6), 362 (100), 272 (4), 135 (5), 106 (5); HRMS calcd for $C_{35}H_{51}NO_4$ (M^+) 549.3818, found 549.3812.

(2*S*,3*S*)-*tert*-Butyl 3-cyclohexyl-3-hydroxy-2-[(*S*)-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino](phenyl)methyl]propanoate (5j): colorless oil; $[\alpha]^{20}_{D} = -60.0$ (*c* 0.9, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35−7.17 (m, 10H), 4.59 (d, J = 11.5 Hz, 1H), 3.91 (d, A part of AB, J_{AB} = 13.7 Hz, 1H), 3.45 (dd, J = 2.2, 11.5 Hz, 1H), 3.30 (d, B part of AB, J_{AB} = 13.7 Hz, 1H), 3.15 (br d, 1H), 3.08 (d, A part of AB, J_{AB} = 14.1 Hz, 1H), 2.94 (d, J = 11.0 Hz, 1H), 2.89 (s, 3H), 2.81 (dt, J = 2.2, 11.2 Hz, 1H), 2.25 (d, B part of AB, J_{AB} = 14.1 Hz, 1H), 1.99 (d, J = 13.4 Hz, 1H), 1.92 (d, J = 12.3 Hz, 1H), 1.79−1.53 (m, 7H), 1.63 (s, 9H), 1.42 (dd, J = 7.3, 12.6 Hz, 1H), 1.24−1.04 (m, 5H), 0.92 (t, J = 8.4 Hz, 1H), 0.84 (s, 3H), 0.82−0.81 (m, 1H), 0.80 (s, 3H), 0.78−0.65 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 140.6, 136.7, 129.7 (2C), 129.7 (2C), 127.9 (2C), 127.6 (2C), 127.0, 126.5, 85.2, 81.9, 75.3, 64.7, 57.1, 54.5, 53.0, 48.6, 47.6, 46.6, 45.0, 42.9, 37.3, 30.0, 29.8, 29.2, 28.4 (3C), 27.4, 26.3, 26.0, 25.9, 21.0, 20.3; IR ($CHCl_3$) 2930, 2853, 1697, 1452, 1367, 1150 cm^{-1}; MS (20 eV) m/z 589 (M^+, 1), 362 (100), 272 (8), 148 (13), 106 (40); HRMS calcd for $C_{38}H_{55}NO_4$ (M^+) 589.4131, found 589.4140.

(2*S*,3*S*)-*tert*-Butyl 3-hydroxy-2-[(*S*)-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino](phenyl)methyl]octanoate (5k): colorless oil; $[\alpha]^{20}_{D} = -64.6$ (*c* 1.1, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36−7.20 (m, 10H), 4.44 (d, J = 11.7 Hz, 1H), 3.90 (d, A part of AB, J_{AB} = 13.7 Hz, 1H), 3.31 (d, B part of AB, J_{AB} = 13.7 Hz, 1H), 3.23 (dd, J = 2.4, 11.5 Hz, 1H), 3.23−3.16 (m, 2H), 3.12 (d, A part of AB, J_{AB} = 14.3 Hz, 1H), 2.94 (d, J = 10.8 Hz, 1H), 2.92 (s, 3H), 2.22 (d, B part of AB, J_{AB} = 14.3 Hz, 1H), 1.68−1.54 (m, 4H), 1.63 (s, 9H), 1.46−1.16 (m, 10H), 0.95−0.90 (m, 1H), 0.85 (d, J = 14.1 Hz, 3H), 0.85 (s, 3H), 0.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.8, 140.6, 136.6, 129.7 (2C), 129.7 (2C), 127.9 (2C), 127.7 (2C), 127.0, 126.5, 85.1, 82.0, 70.7, 64.6, 57.3, 54.5, 53.0, 51.5, 47.6, 46.6, 45.0, 37.3, 36.4, 31.8, 29.8, 28.4 (3C), 27.4, 25.7, 22.5, 20.9, 20.3, 14.0; IR ($CHCl_3$) 3543, 2934, 1699, 1601, 1454, 1367, 1150 cm^{-1}; MS (20 eV) m/z 577 (M^+, 0.4), 362 (100), 272 (6), 242 (6), 148 (26), 106 (73); HRMS calcd for $C_{37}H_{55}NO_4$ (M^+) 577.4131, found 577.4137.

(1*R*,2*R*,6*R*)-*tert*-Butyl 2-(2-*tert*-Butoxy-2-oxoethyl)-6-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]cyclohexanecarboxylate (10a). *n*-Buthyllithium (2.6 M in hexane solution, 107 μL, 0.279 mmol) was added dropwise to a solution of chiral amine **1** (76 mg,

0.279 mmol) in THF (2 mL) at −50 °C, and the solution was stirred for 5 min under an argon atmosphere. A solution of substrate **9a** (55 mg, 0.186 mmol) in THF (1 mL) was added dropwise to the lithium amide solution at the same temperature, and the mixture was stirred for 2.0 h. The reaction mixture was quenched with a saturated aqueous solution of sodium hydrogen carbonate and extracted with diethyl ether. The organic layer was washed with brine, dried over anhydrous sodium sulfate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate =20/1) to afford **10a** as a single diastereomer (89 mg, 85%) as well as a mixture of minor diastereomer (7 mg, 6%): colorless oil; $[\alpha]_D^{20}$ = −29.3 (*c* 0.9, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.34 (d, *J* = 7.4 Hz, 2H), 7.27 (t, *J* = 7.4 Hz, 2H), 7.19 (br t, *J* = 7.4 Hz, 1H), 3.78 (d, A part of AB, J_{AB} = 14.7 Hz, 1H), 3.72 (d, B part of AB, J_{AB} = 14.7 Hz, 1H), 3.19 (d, A part of AB, J_{AB} = 14.1 Hz, 1H), 3.19−3.18 (m, 1H), 3.07 (s, 3H), 2.96−2.92 (m, 1H), 2.30 (d, B part of AB, J_{AB} = 14.1 Hz, 1H), 2.30−2.21 (m, 2H), 1.98−1.91 (m, 2H), 1.86−1.84 (m, 1H), 1.73−1.67 (m, 3H), 1.62−1.55 (m, 2H), 1.53 (s, 9H), 1.46 (dd, *J* = 7.4, 12.7 Hz, 1H), 1.48−1.44 (m, 1H), 1.43 (s, 9H), 1.40−1.12 (m, 3H), 0.94−0.86 (m, 2H), 0.92 (s, 3H), 0.76 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.6, 171.8, 141.8, 129.0 (2C), 127.8 (2C), 126.2, 85.3, 80.4, 80.1, 62.0, 55.8, 54.7, 53.8, 53.3, 47.4, 45.3, 40.3, 38.1, 37.4, 30.8, 30.5, 29.6, 28.2 (3C), 28.1 (4C), 27.3, 24.8, 20.8, 20.5; IR ($CHCl_3$) 3030, 2936, 1717, 1603, 1456, 1367, 1153 cm^{-1}; MS (20 eV) *m*/*z* 569 (M^+, 45), 312 (87), 284 (61), 135 (22), 91 (100); HRMS calcd for $C_{35}H_{55}NO_5$ (M^+) 569.4080, found 569.4083.

(1*R*,2*R*,5*R*)-*tert*-Butyl 2-(2-*tert*-Butoxy-2-oxoethyl)-5-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]-cyclopentanecarboxylate (10b). *n*-Buthyllithium (2.6 M in hexane solution, 202 μL, 0.533 mmol) was added dropwise to a solution of chiral amine **1** (146 mg, 0.533 mmol) in THF (4 mL) at −50 °C, and the solution was stirred for 5 min under an argon atmosphere. A solution of substrate **9b** (100 mg, 0.355 mmol) in THF (10 mL) was added dropwise to the lithium amide solution at the same temperature, and the mixture was stirred for 2.0 h. The reaction mixture was quenched with a saturated aqueous solution of sodium hydrogen carbonate and extracted with diethyl ether. The organic layer was washed with brine, dried over anhydrous sodium sulfate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate = 30/1 → 20/1 → 10/1 → ethyl acetate) to afford **10b** as a single diastereomer (168 mg, 85%) as well as a mixture of minor diastereomers (21 mg, 11%): colorless oil; $[\alpha]^{25}_D$ = −40.0 (*c* 0.4, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (d, *J* = 6.8 Hz, 2H), 7.29−7.24 (m, 2H), 7.18 (br t, *J* = 7.4 Hz, 1H), 3.74 (d, A part of AB, J_{AB} = 15.2 Hz, 1H), 3.66 (d, B part of AB, J_{AB} = 15.2 Hz, 1H), 3.54 (dt, *J* = 8.4, 8.7 Hz, 1H), 3.30 (dd, *J* = 7.1, 7.3 Hz, 1H), 3.11 (s, 3H), 2.99 (d, A part of AB, J_{AB} = 13.7 Hz, 1H), 2.49 (t, *J* = 8.7 Hz, 1H), 2.40 (dd, A part of AB, J_{AB} = 14.5 Hz, *J* = 8.8 Hz, 1H), 2.34 (m, 1H), 2.27 (d, B part of AB, J_{AB} = 13.7 Hz, 1H), 2.10 (dd, B part of AB, J_{AB} = 14.5 Hz, *J* = 9.5 Hz, 1H), 1.92−1.18 (m, 10H), 1.45 (s, 9H), 1.42 (s, 9H), 1.00−0.88 (m, 1H), 0.96 (s, 3H), 0.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.1, 171.7, 141.4, 128.0 (2C), 127.9 (2C), 126.2, 85.3, 80.1, 79.9, 67.1, 57.4, 54.8, 53.1, 52.3, 47.4, 47.3, 45.3, 40.3, 37.4, 30.7, 30.2, 28.1 (7C), 27.2, 27.1, 20.8, 20.4; IR ($CHCl_3$) 3030, 2951, 1717, 1456, 1367, 1198, 1148 cm^{-1}; MS (70 eV) *m*/*z* 555 (M^+, 10), 402 (18), 312 (100), 284 (15), 272 (56), 135 (26), 91 (79); HRMS calcd for $C_{34}H_{53}NO_5$ (M^+) 555.3923, found 555.3915.

A typical procedure for the tandem double Michael−aldol reaction was shown by representing the reaction of **1**, **9a**, and **4a**. The major products (**11a**−**f**) were isolated as a single diastereomer by employing silica gel column chromatography or recycle HPLC.

(1*R*,2*S*,6*R*)-*tert*-Butyl 2-[(2*S*,3*S*)-1-*tert*-Butoxy-3-hydroxy-1-oxo-3-phenylpropan-2-yl]-6-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]cyclohexanecarboxylate (11a). *n*-Buthyllithium (2.6 M in hexane solution, 110 μL, 0.285 mmol) was added dropwise to a solution of chiral amine **1** (78 mg, 0.285 mmol) in THF (2 mL) at −50 °C, and the solution was stirred for 5 min under an argon atmosphere. A solution of substrate **9a** (57 mg, 0.192 mmol) in THF (1 mL) was added dropwise to the lithium amide solution at the same temperature, and the mixture was stirred for 0.5 h. Then, benzaldehyde (**4a**) (58 μL, 0.576 mmol) was added dropwise to the reaction mixture at the same temperature, and the mixture was stirred for 2 h. The reaction mixture was quenched with a saturated aqueous solution of sodium hydrogen carbonate and extracted with diethyl ether. The organic layer was washed with brine, dried over anhydrous sodium sulfate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate =20/1) to afford **11a** as a single diastereomer (77 mg, 60%) as well as the mixture of minor diastereomers (15 mg, 11%): colorless oil; $[\alpha]^{23}_D$ = −16.2 (*c* 0.4, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36−7.17 (m, 10H), 4.82 (dd, *J* = 6.0, 10.4 Hz, 1H), 3.85 (d, A part of AB, J_{AB} = 14.5 Hz, 1H), 3.81 (d, B part of AB, J_{AB} = 14.5 Hz, 1H), 3.28 (d, A part of AB, J_{AB} = 13.7 Hz, 1H), 3.18 (dd, *J* = 3.1, 7.3 Hz, 1H), 3.09 (s, 3H), 3.04−2.99 (m, 2H), 2.71 (br d, *J* = 9.9 Hz, 1H), 2.33 (d, B part of AB, J_{AB} = 13.7 Hz, 1H), 2.05−1.80 (m, 3H), 1.72−1.53 (m, 4H), 1.64 (s, 9H), 1.49−1.21 (m, 6H), 1.17−1.10 (m, 1H), 1.12 (s, 9H), 0.92−0.88 (m, 1H), 0.92 (s, 3H), 0.73 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.4, 171.6, 142.9, 142.0, 129.0 (2C), 128.2 (2C), 127.8, 127.8 (2C), 127.0 (2C), 126.2, 85.5, 81.1, 80.3, 72.8, 63.6, 55.3, 54.7, 53.5, 53.0, 48.4, 47.4, 45.4, 41.8, 37.4, 30.7 (2C), 28.2 (4C), 27.8 (4C), 27.3, 25.2, 20.8, 20.5; IR ($CHCl_3$) 3692, 2934, 1715, 1603, 1456, 1367, 1151 cm^{-1}; MS (20 eV) *m*/*z* 675 (M^+, 34), 568 (32), 455 (81), 312 (78), 284 (55), 272 (51), 135 (50), 91 (100); HRMS calcd for $C_{42}H_{61}NO_6$ (M^+) 675.4499, found 675.4496.

(1*R*,2*S*,6*R*)-*tert*-Butyl 2-[(2*S*,3*S*)-1-*tert*-butoxy-3-(4-chlorophenyl)-3-hydroxy-1-oxopropan-2-yl]-6-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]cyclohexanecarboxylate (11b): colorless oil; $[\alpha]^{24}_D$ = −25.7 (*c* 0.6, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (d, *J* = 7.8 Hz, 2H), 7.30−7.23 (m, 6H), 7.19 (br t, *J* = 7.2 Hz, 1H), 4.79 (dd, *J* = 5.5, 10.3 Hz, 1H), 3.85 (d, A part of AB, J_{AB} = 15.0 Hz, 1H), 3.81 (d, B part of AB, J_{AB} = 15.0 Hz, 1H), 3.28 (d, A part of AB, J_{AB} = 14.1 Hz, 1H), 3.19 (dd, *J* = 3.1, 7.3 Hz, 1H), 3.10 (s, 3H), 3.04−2.90 (br, 2H), 2.62 (br d, *J* = 10.4 Hz, 1H), 2.33 (d, B part of AB, J_{AB} = 14.1 Hz, 1H), 2.14−1.96 (br, 1H), 1.96−1.76 (br m, 3H), 1.76−1.51 (m, 4H), 1.63 (s, 9H), 1.50−1.02 (m, 6H), 1.21 (s, 9H), 0.96−0.86 (m, 1H), 0.92 (s, 3H), 0.73 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.5, 171.3, 141.9, 141.6, 133.4, 128.9 (2C), 128.4 (4C), 127.8 (2C), 126.3, 85.5, 81.3, 80.5, 72.0, 63.6, 55.0, 54.7, 53.5, 52.4, 48.0, 47.4, 45.3, 41.4, 37.3, 30.7 (2C), 28.2 (4C), 27.8 (4C), 27.3, 25.2, 20.8, 20.5; IR ($CHCl_3$) 3690, 2936, 1715, 1601, 1456, 1369, 1151 cm^{-1}; MS (70 eV) *m*/*z* 709 (M^+, 14), 568 (6), 455 (13), 312 (29), 282 (17), 272 (12), 135 (23), 91 (100); HRMS calcd for $C_{42}H_{60}ClNO_6$ (M^+) 709.4109, found 709.4114.

(1*R*,2*S*,6*R*)-*tert*-Butyl 2-[(2*S*,3*S*)-1-*tert*-butoxy-3-hydroxy-1-oxo-3-(*p*-tolyl)propan-2-yl]-6-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]cyclohexanecarboxylate (11c): colorless oil; $[\alpha]^{28}_D$ = −27.7 (*c* 1.1, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.34 (d, *J* = 7.2 Hz, 2H), 7.29−7.23 (m, 2H), 7.22−7.15 (m, 1H), 7.19 (d, *J* = 8.0 Hz, 2H), 7.09 (d, *J* = 8.0 Hz, 2H), 4.78 (dd, *J* = 5.5, 10.3 Hz, 1H), 3.85 (d, A part of AB, J_{AB} = 14.3 Hz, 1H), 3.79 (d, B part of AB, J_{AB} = 14.3 Hz, 1H), 3.27 (d, A part of AB, J_{AB} = 14.5 Hz, 1H), 3.17 (dd, *J* = 3.0, 7.2 Hz, 1H), 3.08 (s, 3H), 3.06−2.90 (br, 2H), 2.69 (d, *J* = 10.1 Hz, 1H), 2.32 (d, B part of AB, J_{AB} = 14.5 Hz, 1H), 2.30 (s, 3H), 2.11−1.76 (m, 4H), 1.74−1.06 (m, 10H), 1.63 (s, 9H), 1.17 (s, 9H), 0.96−0.84 (m, 1H), 0.92 (s, 3H), 0.72 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.3, 171.6, 141.9, 140.0, 137.4, 128.8 (4C), 127.7 (2C), 126.9 (2C), 126.2, 85.5, 81.0, 80.1, 72.6, 63.6, 55.4, 54.7, 53.5, 53.2, 48.2, 47.3, 45.3, 41.7, 37.3, 30.6 (2C), 28.2 (4C), 27.7 (4C), 27.2, 25.2, 21.1, 20.8, 20.5; IR

($CHCl_3$) 3690, 2936, 1715, 1603, 1456, 1369, 1151 cm^{-1}; MS (70 eV) *m*/*z* 689 (M^+, 11), 568 (15), 455 (47), 312 (57), 282 (42), 272 (39), 135 (45), 91 (100); HRMS calcd for $C_{43}H_{63}NO_6$ (M^+) 689.4655, found 689.4662.

(1*R*,2*S*,6*R*)-*tert*-Butyl 2-[(2*S*,3*S*)-1-*tert*-butoxy-3-hydroxy-3-(4-methoxyphenyl)-1-oxopropan-2-yl]-6-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]cyclohexanecarboxylate (11d): colorless oil; $[\alpha]^{19}_D$ = −38.3 (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 7.2 Hz, 2H), 7.29−7.16 (m, 3H), 7.24 (d, *J* = 8.8 Hz, 2H), 6.83 (d, *J* = 8.8 Hz, 2H), 4.77 (dd, *J* = 4.8, 9.9 Hz, 1H), 3.85 (d, A part of AB, J_{AB} = 14.5 Hz, 1H), 3.80 (d, B part of AB, J_{AB} = 14.5 Hz, 1H), 3.77 (s, 3H), 3.27 (d, A part of AB, J_{AB} = 14.1 Hz, 1H), 3.18 (dd, *J* = 3.1, 7.1 Hz, 1H), 3.09 (s, 3H), 3.30−2.90 (br, 2H), 2.68 (br d, *J* = 10.6 Hz, 1H), 2.33 (d, B part of AB, J_{AB} = 14.1 Hz, 1H), 2.08−1.78 (m, 4H), 1.76−1.50 (m, 4H), 1.64 (s, 9H), 1.50−1.10 (m, 6H), 1.18 (s, 9H), 0.94−0.85 (m, 1H), 0.92 (s, 3H), 0.73 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.4, 171.6, 159.2, 142.0, 135.3, 129.1 (2C), 128.2, 128.1, 127.8 (2C), 126.2, 113.6 (2C), 85.4, 81.0, 80.2, 72.2, 63.6, 55.3, 55.2, 54.7, 54.0, 53.5, 48.0, 47.4, 45.3, 41.8, 37.3, 30.6 (2C), 28.2 (4C), 27.8 (4C), 27.2, 25.2, 20.8, 20.5; IR ($CHCl_3$) 3692, 2936, 1715, 1611, 1456, 1369, 1151 cm^{-1}; MS (70 eV) *m*/*z* 705 (M^+, 26), 568 (22), 455 (88), 312 (77), 284 (56), 272 (59), 135 (56), 91 (100); HRMS calcd for $C_{43}H_{63}NO_7$ (M^+) 705.4604, found 705.4601.

(1*R*,2*S*,6*R*)-*tert*-Butyl 2-[(2*S*,3*R*)-1-*tert*-butoxy-3-hydroxy-4-methyl-1-oxopentan-2-yl]-6-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]cyclohexanecarboxylate (11e): colorless oil; $[\alpha]^{21}_D$ = −35.3 (*c* 1.1, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, *J* = 7.2 Hz, 2H), 7.26 (t, *J* = 7.2 Hz, 2H), 7.18 (br t, *J* = 7.2 Hz, 1H), 3.81 (d, A part of AB, J_{AB} = 14.5 Hz, 1H), 3.77 (d, B part of AB, J_{AB} = 14.5 Hz, 1H), 3.74 (br, 1H), 3.24 (br d, A part of AB, J_{AB} = 14.1 Hz, 1H), 3.15 (dd, *J* = 3.1, 7.3 Hz, 1H), 3.08 (s, 3H), 2.91 (br, 2H), 2.39 (dd, *J* = 1.5, 11.2 Hz, 1H), 2.30 (d, A part of AB, J_{AB} = 14.1 Hz, 1H), 1.96−1.03 (m, 15H), 1.59 (s, 9H), 1.44 (s, 9H), 0.98 (d, *J* = 6.9 Hz, 3H), 0.95−0.82 (m, 1H), 0.91 (s, 3H), 0.83 (d, *J* = 6.9 Hz, 3H), 0.71 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.2, 172.5, 142.0, 128.9 (2C), 127.8 (2C), 126.2, 85.4, 81.1, 80.2, 73.0, 63.4, 55.0, 54.6 (2C), 53.5, 47.4, 45.3 (2C), 37.3 (2C), 31.4, 30.7, 28.1 (8C), 27.2 (2C), 25.3, 20.8, 20.5, 20.4, 14.0; IR ($CHCl_3$) 2935, 1715, 1603, 1457, 1367, 1157 cm^{-1}; MS (70 eV) *m*/*z* 641 (M^+, 39), 598 (13), 568 (25), 455 (38), 312 (85), 284 (56), 272 (47), 135 (52), 91 (100); HRMS calcd for $C_{39}H_{63}NO_6$ (M^+) 641.4655, found 641.4646.

(1*R*,2*S*,6*R*)-*tert*-Butyl 2-[(2*S*,3*R*)-1-*tert*-butoxy-3-cyclohexyl-3-hydroxy-1-oxopropan-2-yl]-6-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino]cyclohexanecarboxylate (11f): colorless oil; $[\alpha]^{21}_D$ = −33.7 (*c* 0.9, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, *J* = 7.8 Hz, 2H), 7.28−7.23 (m, 2H), 7.18 (br t, *J* = 7.2 Hz, 1H), 3.81 (d, A part of AB, J_{AB} = 14.8 Hz, 1H), 3.77 (d, B part of AB, J_{AB} = 14.8 Hz, 1H), 3.68 (br, 1H), 3.23 (br d, A part of AB, J_{AB} = 14.0 Hz, 1H), 3.14 (dd, *J* = 3.2, 7.2 Hz, 1H), 3.07 (s, 3H), 2.89 (br, 2H), 2.45 (dd, *J* = 1.2, 10.8 Hz, 1H), 2.30 (d, A part of AB, J_{AB} = 14.0 Hz, 1H), 1.90−1.02 (m, 25H), 1.59 (s, 9H), 1.45 (s, 9H), 0.94−0.82 (m, 1H), 0.91 (s, 3H), 0.71 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.4, 172.5, 142.0, 128.9 (2C), 127.8 (2C), 126.2, 85.4, 81.1, 80.2, 73.2, 63.4, 55.0, 54.6 (2C), 53.5, 47.4, 45.3 (2C), 41.9 (2C), 37.3, 30.67 (2C), 30.64, 28.15 (5C), 28.11 (4C), 27.2, 26.7, 26.4, 25.3, 24.6, 20.8, 20.5; IR ($CHCl_3$): 3692, 2932, 1715, 1603, 1452, 1367, 1153 cm^{-1}; MS (70 eV) *m*/*z* 681 (M^+, 23), 624 (8), 455 (47), 312 (77), 284 (58), 272 (52), 135 (54), 91 (100); HRMS calcd for $C_{42}H_{67}NO_6$ (M^+) 681.4968, found 681.4959.

(2*S*,3*R*)-*tert*-Butyl 3-Acetoxy-2-[(*S*)-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino](phenyl)methyl]-3-phenylpropanoate (13a). Acetic anhydride (2.8 mL, 29.9 mmol), pyridine (3.0 mL, 37.4 mmol), and 4-dimethylaminopyridine (9 mg, 0.07 mmol) were added to a solution of **5b** (437 mg, 0.75 mmol) in THF (8 mL) at room temperature, and the resulting mixture was stirred for 5 h at the same temperature under a nitrogen atmosphere. The reaction was quenched with methanol at 0 °C, and the solvent was removed in vacuo. The residue was added saturated aqueous solution of ammonium chloride and extracted with ethyl acetate. The organic layer was washed with brine, dried over sodium sulfate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate = 10/1) to afford **13a** (449 mg, 96%): colorless oil; $[\alpha]^{22}_D$ = −65.8 (*c* 1.1, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39−7.10 (m, 15H), 5.58 (d, *J* = 4.4 Hz, 1H), 4.39 (d, *J* = 11.2 Hz, 1H), 3.89 (d, A part of AB, J_{AB} = 13.9 Hz, 1H), 3.63 (dd, *J* = 4.6, 11.2 Hz, 1H), 3.33 (d, B part of AB, J_{AB} = 13.9 Hz, 1H), 3.24 (d, A part of AB, J_{AB} = 14.3 Hz, 1H), 3.27−3.22 (br, 1H), 2.97 (s, 3H), 2.18 (d, B part of AB, J_{AB} = 14.3 Hz, 1H), 1.91 (s, 3H), 1.71−1.54 (m, 4H), 1.44 (dd, *J* = 7.3, 12.6 Hz, 1H), 1.31−1.20 (m, 1H), 1.25 (s, 9H), 0.97−0.92 (m, 1H), 0.87 (s, 3H), 0.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 169.1, 140.2, 138.4, 135.4, 129.9 (2C), 129.6 (2C), 128.0 (2C), 128.0 (2C), 127.7 (2C), 127.4, 127.3, 126.7, 125.8 (2C), 84.7, 80.6, 73.6, 64.7, 57.9, 54.4, 53.3, 53.1, 47.6, 46.9, 45.0, 37.2, 29.6, 28.0 (3C), 27.4, 20.9, 20.7, 20.3; IR ($CHCl_3$) 2936, 1726, 1603, 1494, 1452, 1369, 1148 cm^{-1}; MS (20 eV) *m*/*z* 625 (M^+, 1), 362 (100), 272 (7), 148 (10), 106 (6); HRMS calcd for $C_{40}H_{51}NO_5$ (M^+) 625.3767, found 625.3761.

(2*S*,3*R*)-*tert*-Butyl 3-(*tert*-Butoxycarbonyloxy)-2-[(*S*)-[(1*S*,2*R*)-2-methoxybornyl-10-benzylamino](phenyl)methyl]-3-phenylpropanoate (13b). Compound **13b** was prepared in the same way as in the case of **8b**: colorless oil; $[\alpha]^{25}_D$ = −51.9 (*c* 1.2, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, *J* = 7.5 Hz, 2H), 7.32−7.12 (m, 11H), 7.11 (br d, *J* = 7.6 Hz, 2H), 5.38 (d, *J* = 4.9 Hz, 1H), 4.45 (d, *J* = 11.0 Hz, 1H), 3.92 (d, A part of AB, J_{AB} = 14.1 Hz, 1H), 3.60 (dd, *J* = 4.9, 11.0 Hz, 1H), 3.34 (d, B part of AB, J_{AB} = 14.1 Hz, 1H), 3.22−3.16 (br, 1H), 3.18 (d, A part of AB, J_{AB} = 14.7 Hz, 1H), 2.94 (s, 3H), 2.21 (d, B part of AB, J_{AB} = 14.7 Hz, 1H), 1.68−1.57 (m, 4H), 1.42 (dd, *J* = 7.3, 12.6 Hz, 1H), 1.32−1.22 (m, 1H), 1.28 (s, 9H), 1.27 (s, 9H), 0.96−0.90 (m, 1H), 0.86 (s, 3H), 0.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 152.2, 140.4, 138.7, 135.7, 130.0 (2C), 129.5 (2C), 128.0 (2C), 127.9 (2C), 127.7 (2C), 127.2, 127.2, 126.6, 125.9 (2C), 84.8, 81.6, 80.6, 76.4, 65.1, 57.7, 54.4, 53.7, 53.1, 47.6, 47.2, 45.0, 37.2, 29.7, 28.0 (3C), 27.7 (3C), 27.4, 20.9, 20.3; IR ($CHCl_3$) 2936, 1742, 1603, 1495, 1454, 1369, 1286, 1148, 1097 cm^{-1}; MS (20 eV) *m*/*z* 683 (M^+, 1), 362 (100), 272 (8), 204 (4), 148 (21), 106 (22); HRMS calcd for $C_{43}H_{57}NO_6$ (M^+) 683.4186, found 683.4191.

(2*S*,3*R*)-*tert*-Butyl 2-[(*S*)-[(1*S*,2*R*)-2-Methoxybornyl-10-benzylamino](phenyl)methyl]-3-phenyl-3-(triethylsilyloxy)propanoate (13c). Triethylchlorosilane (251 μL, 1.492 mmol) and imidazole (127 mg, 1.865 mmol) were added to a solution of **5b** (218 mg, 0.373 mmol) in dichloromethane (5 mL) at 0 °C, and the reaction mixture was stirred for 28 h at room temperature under an argon atmosphere. The reaction mixture was poured into saturated aqueous solution of ammonium chloride and extracted with ethyl acetate. The organic layer was washed with brine, dried over sodium sulfate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate = 20/1) to afford **13c** (262 mg, 100%): colorless oil; $[\alpha]^{25}_D$ = −47.9 (*c* 0.9, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 (d, *J* = 7.6 Hz, 2H), 7.34 (t, *J* = 7.6 Hz, 2H), 7.31−7.12 (m, 11H), 4.70 (d, *J* = 3.1 Hz, 1H), 4.42 (d, *J* = 11.4 Hz, 1H), 3.89 (d, A part of AB, J_{AB} = 13.9 Hz, 1H), 3.35 (dd, *J* = 3.1, 11.4 Hz, 1H), 3.34 (d, B part of AB, J_{AB} = 13.9 Hz, 1H), 3.20 (dd, *J* = 3.1, 7.3 Hz, 1H), 3.11 (d, A part of AB, J_{AB} = 14.3 Hz, 1H), 2.87 (s, 3H), 2.25 (d, B part of AB, J_{AB} = 14.3 Hz, 1H), 1.64 (dq, *J* = 3.6, 12.5 Hz, 1H), 1.57−1.45 (m, 3H), 1.41 (dd, *J* = 7.2, 12.7 Hz, 1H), 1.35 (s, 9H), 1.25−1.19 (m, 1H), 0.93−0.87 (m, 1H), 0.85 (s, 3H), 0.78 (s, 3H), 0.64 (t, *J* = 8.0 Hz, 9H), 0.15 (dq, A part of AB, J_{AB} = 14.9 Hz, *J* = 8,0 Hz, 3H), 0.10 (dq, B part of AB, J_{AB} = 14.9 Hz, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.3, 143.5, 140.8, 137.2, 130.2 (2C), 129.9 (2C), 127.7 (2C), 127.6

(2C), 127.5 (2C), 126.8, 126.7, 126.4 (3C), 84.8, 79.7, 73.6, 63.8, 57.6, 56.0, 54.4, 53.0, 47.7, 46.3, 45.1, 37.3, 29.7, 28.2 (3C), 27.3, 20.9, 20.3, 6.7 (3C), 4.6 (3C); IR ($CHCl_3$) 2955, 1724, 1603, 1495, 1452, 1367, 1146 cm^{-1}; MS (20 eV) *m*/*z* 697 (M^+, 0.7), 362 (100), 272 (7), 106 (12); HRMS calcd for $C_{44}H_{63}NO_4Si$ (M^+) 697.4526, found 697.4521.

(2S,3*R*)-*tert*-Butyl 2-[(*S*)-Acetamido(phenyl)methyl]-3-hydroxy-3-phenylpropanoate (14a). *N*-Iodosuccinimide (NIS) (36 mg, 0.161 mmol) was added to a solution of **13a** (25 mg, 0.04 mmol) in dichloromethane (1.0 mL) at room temperature under an argon atmosphere, and the reaction mixture was stirred for 6 h at the same temperature. The reaction mixture was poured into saturated aqueous solution of sodium hydrogen carbonate and extracted with chloroform. The organic layer was washed with a saturated aqueous solution of sodium thiosulfate followed by brine, dried over potassium carbonate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate = 5/1 → chloroform/methanol = 20/1) to afford **14a** (14 mg, 96%) and **2**[9] (6.9 mg, 95%): colorless plate; mp 145−147 °C (diethyl ether); $[\alpha]^{23}_D$ = +27.5 (*c* 0.5, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40−7.16 (m, 10H), 7.14 (br, 1H), 4.97 (dd, *J* = 5.3, 8.7 Hz, 1H), 4.84 (dd, *J* = 5.5, 8.1 Hz, 1H), 3.04 (dd, *J* = 5.3, 8.1 Hz, 1H), 2.72 (d, *J* = 5.7 Hz, 1H), 2.08 (s, 3H), 1.26 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.0, 169.0, 141.2, 139.8, 128.8 (2C), 128.5 (2C), 128.4, 127.4, 126.2 (4C), 82.4, 73.7, 58.6, 52.0, 27.8 (3C), 23.4; IR ($CHCl_3$) 3404, 3034, 1703, 1674, 1506, 1369, 1153 cm^{-1}; MS (CI+) *m*/*z* 370 (M^+ + H, 62); HRMS calcd for $C_{22}H_{28}NO_4$ (M^+ + H) 370.2018, found 370.2016.

(2S,3*R*)-*tert*-Butyl 2-[(*S*)-amino(phenyl)methyl]-3-(*tert*-butoxycarbonyloxy)-3-phenylpropanoate (14b): colorless plate; mp 138−141 °C (diethyl ether); $[\alpha]^{24}_D$ = −8.4 (*c* 0.3, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49−7.47 (m, 2H), 7.39−7.16 (m, 8H), 5.94 (d, *J* = 9.5 Hz, 1H), 3.78 (d, *J* = 5.3 Hz, 1H), 3.11 (dd, *J* = 5.3, 9.7 Hz, 1H), 1.70 (br, 2H), 1.40 (s, 9H), 1.26 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 152.4, 143.6, 137.9, 128.5 (2C), 128.4, 128.3 (2C), 127.3 (2C), 127.1, 126.2 (2C), 82.0, 81.1, 78.3, 59.0, 54.2, 27.7 (3C), 27.7 (3C); IR ($CHCl_3$) 3032, 1742, 1369, 1234, 1157 cm^{-1}; MS (CI+) *m*/*z* 428 (M^+ + H, 100); HRMS calcd for $C_{25}H_{34}NO_5$ (M^+ + H): 428.2437, found 428.2444. Anal. Calcd for $C_{25}H_{33}NO_5$: C, 70.23; H, 7.78; N, 3.28. Found: C, 69.99; H, 7.80; N, 3.11.

(2S,3*R*)-*tert*-Butyl 2-[(*S*)-amino(phenyl)methyl]-3-phenyl-3-(triethylsilyloxy) propanoate (14c): colorless oil; $[\alpha]^{21}_D$ = +19.3 (*c* 0.8, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48 (br d, *J* = 7.1 Hz, 2H), 7.34 (br t, *J* = 7.1 Hz, 2H), 7.29 (br t, *J* = 7.1 Hz, 1H), 7.25 (br t, *J* = 7.5 Hz, 2H) 7.19−7.13 (m, 3H), 5.14 (d, *J* = 9.2 Hz, 1H), 3.60 (d, *J* = 4.6 Hz, 1H), 2.96 (dd, *J* = 4.6, 9.2 Hz, 1H), 1.73 (br, 2H), 1.22 (s, 9H), 0.81 (t, *J* = 8.0 Hz, 9H), 0.44 (dq, A part of AB J_{AB} = 15.0 Hz, *J* = 8.0 Hz, 3H), 0.39 (dq, B part of AB J_{AB} = 15.0 Hz, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 144.3, 142.7, 128.2 (2C), 128.0 (2C), 127.8, 127.2 (2C), 126.7, 126.2 (2C), 80.4, 75.0, 62.1, 54.3, 27.9 (3C), 6.7 (3C), 4.8 (3C); IR ($CHCl_3$) 3015, 2955, 1709, 1454, 1367, 1234, 1198, 1151 cm^{-1}; MS (20 eV) *m*/*z* 441 (M^+, 0.6), 356 (5), 233 (10), 208 (6), 164 (10), 106 (100); HRMS calcd for $C_{26}H_{39}NO_3Si$ (M^+) 441.2699, found 441.2695.

(2S,3*R*)-*tert*-Butyl 2-[(*S*)-[(1*S*,2*R*)-2-methoxybornyl-10-amino]-(phenyl)methyl]-3-phenyl-3-(triethylsilyloxy)propanoate (8c): colorless plate; mp 80−82 °C (diethyl ether); $[\alpha]^{19}_D$ = −26.8 (*c* 0.6, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (br d, *J* = 7.3 Hz, 2H), 7.34 (br t, *J* = 7.3 Hz, 2H), 7.28 (br t, *J* = 7.3 Hz, 1H), 7.23 (t, *J* = 7.3 Hz, 2H), 7.14 (br t, *J* = 7.3 Hz, 1H), 7.05 (br d, *J* = 7.3 Hz, 2H), 5.37 (d, *J* = 9.7 Hz, 1H), 3.52 (dd, *J* = 3.4, 7.4 Hz, 1H), 3.34 (s, 3H), 3.13 (d, *J* = 3.9 Hz, 1H), 2.79 (dd, *J* = 4.0, 9.7 Hz, 1H), 2.70 (d, A part of AB, J_{AB} = 10.6 Hz, 1H), 2.26 (br, 1H), 1.82−1.54 (m, 6H), 1.71 (d, B part of AB, J_{AB} = 10.6 Hz, 1H), 1.21 (s, 9H), 1.13−1.07 (m, 1H), 0.91 (s, 3H), 0.81 (t, *J* = 8.0 Hz, 9H), 0.77 (s, 3H), 0.43 (dq, A part of AB, J_{AB} = 15.0 Hz, *J* = 8.0 Hz, 3H), 0.39 (dq, B part of AB, J_{AB} = 15.0 Hz, *J* = 8.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 143.3, 141.6, 127.9 (2C), 127.9 (2C), 127.5, 127.5 (2C), 127.0 (2C), 126.2, 86.2, 79.8, 75.1, 63.2, 61.2, 55.7, 53.1, 46.4, 45.8, 45.7, 37.5, 32.3, 27.9 (3C), 27.3, 20.5, 20.5, 6.7 (3C), 4.8 (3C); IR ($CHCl_3$) 3032, 2954, 1717, 1454, 1367, 1198, 1151 cm^{-1}; MS (20 eV) *m*/*z* 607 (M^+, 0.8), 272 (100), 240 (11), 106 (13); HRMS calcd for $C_{37}H_{57}NO_4Si$ (M^+) 607.4057, found 607.4049.

(1*R*, 2*R*, 6*S*)-*tert*-Butyl 2-Amino-6-[(2*S*,3*S*)-1-*tert*-butoxy-3-hydroxy-1-oxo-3-phenylpropan-2-yl]cyclohexanecarboxylate (16a). *N*-Iodosuccinimide (NIS) (26 mg, 0.117 mmol) was added to a solution of **11a** (20 mg, 0.029 mmol) in dichloromethane (1.5 mL) at room temperature under an argon atmosphere, and the reaction mixture was stirred for 6 h at the same temperature. The reaction mixture was poured into a saturated aqueous solution of sodium hydrogen carbonate and extracted with chloroform. The organic layer was washed with saturated aqueous solution of sodium thiosulfate followed by brine, dried over potassium carbonate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate = 10/1 → 0/100 → chloroform/methanol = 20/1) to afford **16a** (9.3 mg, 76%) and **2**[9] (3.9 mg, 74%): colorless oil; $[\alpha]^{21}_D$ = +19.4 (*c* 0.5, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) H of O*H* and NH_2 were not detected. δ 7.36−7.20 (m, 5H), 4.76 (d, *J* = 11.1 Hz, 1H), 2.79 (dt, *J* = 3.7, 11.1 Hz, 1H), 2.71 (dd, *J* = 2.1, 11.1 Hz, 1H), 2.48 (t, *J* = 11.1 Hz, 1H), 2.18−2.10 (br m, 1H), 1.98−1.88 (m, 2H), 1.87−1.79 (m, 1H), 1.59 (s, 9H), 1.44−1.38 (m, 2H), 1.16 (s, 9H), 1.15−1.07 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.0, 171.3, 142.4, 128.3 (2C), 127.9, 127.1 (2C), 81.6, 80.4, 72.7, 58.0, 57.5, 54.3, 39.4, 35.7, 28.2, 28.1 (3C), 27.7 (3C), 24.6; IR ($CHCl_3$) 2934, 1715, 1458, 1369, 1151 cm^{-1}; MS (70 eV) *m*/*z* 419 (M^+, 1), 362 (7), 288 (16), 244 (12), 201 (14), 140 (100); HRMS calcd for $C_{24}H_{37}NO_5$ (M^+) 419.2671, found 419.2676.

(1*R*,2*R*,6*S*)-*tert*-Butyl 2-amino-6-[(2*S*,3*S*)-1-*tert*-butoxy-3-(4-chlorophenyl)-3-hydroxy-1-oxopropan-2-yl]cyclohexanecarboxylate (16b): colorless oil; $[\alpha]^{20}_D$ = +11.8 (*c* 0.7, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): H of O*H* was not detected. δ 7.30−7.23 (m, 4H), 4.73 (d, *J* = 11.0 Hz, 1H), 2.78 (dt, *J* = 3.5, 10.7 Hz, 1H), 2.62 (dd, *J* = 2.1, 11.0 Hz, 1H), 2.44 (t, *J* = 10.7 Hz, 1H), 2.18−2.10 (br m, 1H), 1.96−1.86 (m, 2H), 1.86−1.80 (m, 1H), 1.60−1.25 (br, 2H), 1.58 (s, 9H), 1.44−1.35 (m, 2H), 1.20 (s, 9H), 1.17−1.05 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.1, 171.1, 141.1, 133.5, 128.44 (2C), 128.37 (2C), 81.7, 80.7, 71.9, 57.8, 54.3, 39.3, 35.7, 29.7, 28.4, 28.1 (3C), 27.8 (3C), 24.6; IR ($CHCl_3$) 2934, 1715, 1477, 1369, 1151 cm^{-1}; MS (20 eV) *m*/*z* 453 (M^+, 5), 396 (14), 380 (7), 201 (24), 140 (100); HRMS calcd for $C_{24}H_{36}ClNO_5$ (M^+) 453.2282, found 453.2285.

(1*R*,2*R*,6*S*)-*tert*-Butyl 2-amino-6-[(2*S*,3*S*)-1-*tert*-butoxy-3-hydroxy-1-oxo-3-(*p*-tolyl)propan-2-yl]cyclohexanecarboxylate (16c): colorless oil; $[\alpha]^{22}_D$ = +13.3 (*c* 0.7, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) H of O*H* and NH_2 were not detected. δ 7.20 (d, *J* = 8.0 Hz, 2H), 7.10 (d, *J* = 8.0 Hz, 2H), 4.73 (d, *J* = 11.0 Hz, 1H), 2.79 (dt, *J* = 3.5, 11.2 Hz, 1H), 2.70 (dd, *J* = 2.0, 11.0 Hz, 1H), 2.48 (t, *J* = 11.2 Hz, 1H), 2.31 (s, 3H), 2.16−2.08 (br m, 1H), 1.98−1.87 (m, 2H), 1.86−1.79 (m, 1H), 1.59 (s, 9H), 1.44−1.37 (m, 2H), 1.17 (s, 9H), 1.17−1.07 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.1, 171.5, 139.7, 137.7, 129.1 (2C), 127.1 (2C), 81.7, 80.5, 72.6, 58.4, 57.6, 54.5, 39.7, 35.9, 29.9, 28.3 (3C), 28.0 (3C), 24.8, 21.3; IR ($CHCl_3$) 2936, 1715, 1458, 1369, 1151 cm^{-1}; MS (20 eV) *m*/*z* 433 (M^+, 3), 376 (9), 360 (5), 201 (29), 140 (100); HRMS calcd for $C_{25}H_{39}NO_5$ (M^+) 433.2828, found 433.2824.

(1*R*,2*R*,6*S*)-*tert*-Butyl 2-amino-6-[(2*S*,3*S*)-1-*tert*-butoxy-3-hydroxy-3-(4-methoxyphenyl)-1-oxopropan-2-yl]cyclohexanecarboxylate (16d): colorless oil; $[\alpha]^{20}_D$ = +7.4 (*c* 0.7, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) H of O*H* was not detected, δ 7.24 (d, *J* = 8.8 Hz, 2H), 6.84 (d, *J* = 8.8 Hz, 2H), 4.72 (d, *J* = 11.0 Hz, 1H),

3.78 (s, 3H), 2.78 (br t, J = 10.8 Hz, 1H), 2.69 (dd, J = 2.0, 11.0 Hz, 1H), 2.47 (t, J = 10.8 Hz, 1H), 2.17−2.08 (br m, 1H), 1.98−1.87 (m, 2H), 1.86−1.76 (m, 1H), 1.60−1.30 (br, 2H), 1.59 (s, 9H), 1.45−1.36 (m, 2H), 1.18 (s, 9H), 1.17−1.07 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.8, 171.3, 159.2, 134.8, 128.2 (2C), 113.6 (2C), 81.0, 80.4, 72.2, 57.8 (br), 57.4 (br), 55.3, 54.2, 39.5, 35.4, 29.7, 28.1 (3C), 27.8 (3C), 24.6; IR ($CHCl_3$) 2934, 1715, 1460, 1369, 1151 cm^{-1}; MS (70 eV) m/z 449 (M^+, 5), 392 (6), 376 (6), 320 (13), 313 (67), 257 (45), 201 (100), 140 (64); HRMS calcd for $C_{25}H_{39}NO_6$ (M^+) 449.2777, found 449.2771.

(3*S*,4*S*)-4-Phenyl-3-[(*R*)-phenyl(triethylsilyloxy)methyl]azetidin-2-one (17). A solution of **14c** (30 mg, 0.067 mmol) in THF (1 mL) was added dropwise to a solution of lithium diisopropylamide (1.09 M in THF solution, 186 μL, 0.202 mmol) in THF (2 mL) at −78 °C, and the reaction mixture was stirred for 3 h at the same temperature under an argon atmosphere. The reaction mixture was poured into saturated aqueous solution of sodium hydrogen carbonate and extracted with ethyl acetate. The organic layer was washed with brine, dried over sodium sulfate, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate = 3/1) to afford **17** (20 mg, 82%): colorless oil; $[\alpha]^{19}_D$ = +25.9 (c 0.5, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (br d, J = 7.0 Hz, 2H), 7.37−7.23 (m, 8H), 5.96 (br, 1H), 5.17 (d, J = 4.5 Hz, 1H), 4.51 (d, J = 2.4 Hz, 1H), 3.38 (ddd, J = 0.5, 2.4, 4.4 Hz, 1H), 0.87 (t, J = 7.7 Hz, 9H), 0.55 (q, J = 7.7 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 141.0, 139.9, 128.6 (2C), 128.1 (2C), 127.8, 127.8, 126.7 (2C), 125.5 (2C), 71.7, 68.8, 53.1, 6.7 (3C), 4.7 (3C); IR ($CHCl_3$) 3410, 3032, 1759, 1495, 1456, 1234, 1198, 1096 cm^{-1}; MS (CI+) m/z 368 (M^++H, 0.4); HRMS calcd for $C_{22}H_{30}NO_2Si$ (M^+ + H) 368.2046, found 368.2053.

(2*S*,3*R*)-*tert*-Butyl 3-(*tert*-Butoxycarbonyloxy)-2-[(*S*)-[(1*S*,2*R*)-2-methoxybornyl-10-amino](phenyl)methyl]-3-phenylpropanoate (8b). A mixture of **5b** (25.0 mg, 0.043 mmol), 10% Pd/C (3.0 mg), and formic acid (2 drops) in methanol (2.0 mL) was stirred for 15 h at room temperature under a hydrogen atmosphere. The reaction mixture was filtrated with Celite (washing with methanol), and the filtrate was concentrated in vacuo to remove the solvent. The residue was purified with preparative TLC (hexane/ethyl acetate = 5/1) to afford debenzylated compound (21.0 mg, 99%). Di-*tert*-butyl pirocarbonate (114 μL, 0.50 mmol) and 4-dmimethylaminopyridine (20 mg, 0.17 mmol) were added to a solution of the debenzylated compound (41 mg, 0.083 mmol) in dichloromethane (1 mL) at room temperature, and the solution was stirred for 24 h under a nitrogen atmosphere. The reaction mixture was poured into saturated aqueous solution of sodium hydrogen−carbonate and extracted with ethyl acetate. The organic layer was washed with brine, dried over sodium sulfate, and concentrated in vacuo to remove the solvent. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate =40/1) to afford **8b** (28 mg, 58%). **8b** was recrystallized from diethyl ether to give a suitable crystal for X-ray analysis: colorless plate; mp 174−176 °C (diethyl ether); $[\alpha]^{14}_D$ = −52.2 (c 0.7, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (br d, J = 7.3 Hz, 2H), 7.38 (br t, J = 7.3 Hz, 2H), 7.33 (br t, J = 7.3 Hz, 1H), 7.25 (t, J = 7.3 Hz, 2H), 7.17 (br t, J = 7.3 Hz, 1H), 7.07 (d, J = 7.3 Hz, 2H), 6.14 (d, J = 10.4 Hz, 1H), 3.55 (dd, J = 3.4, 7.4 Hz, 1H), 3.34 (s, 3H), 3.26 (d, J = 4.2 Hz, 1H), 2.97 (dd, J = 4.4, 10.4 Hz, 1H), 2.70 (d, A part of AB, J_{AB} = 10.6 Hz, 1H), 2.27 (br, 1H), 1.81−1.58 (m, 6H), 1.71 (d, B part of AB, J_{AB} = 10.6 Hz, 1H), 1.38 (s, 9H), 1.26 (s, 9H), 1.10−1.04 (m, 1H), 0.89 (s, 3H), 0.74 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.9, 152.5, 140.9, 138.5, 128.3 (2C), 128.2, 128.1 (2C), 127.6 (2C), 126.8 (2C), 126.7, 86.1, 81.7, 80.5, 79.0, 61.0, 59.8, 55.6, 53.0, 46.5, 45.9, 45.8, 37.3, 32.3, 27.8 (3C), 27.7 (3C), 27.2, 20.5, 20.4; IR ($CHCl_3$) 2953, 1742, 1603, 1456, 1275, 1157 cm^{-1}; MS (20 eV) m/z 593 (M^+, 1.2), 272 (100), 240 (8), 148 (7), 106 (11); HRMS calcd for $C_{36}H_{51}NO_6$ (M^+) 593.3716, found 593.3710. Anal. Calcd for $C_{36}H_{51}NO_6$: C, 72.82; H, 8.66; N, 2.36. Found: C, 73.11; H, 8.63; N, 2.38.

(1*R*,2*S*,6*R*)-*tert*-Butyl 2-[(2*S*,3*S*)-1-*tert*-Butoxy-3-(*tert*-butoxycarbonyloxy)-1-oxo-3-phenylpropan-2-yl]-6-[(1*S*,2*R*)-2-methoxybornyl-10-amino]cyclohexanecarboxylate (12). Compound **12** was prepared in the same way as debenzylation of **5b**.

12: colorless plate; mp 133−134 °C (methanol); $[\alpha]^{18}_D$ = −47.0 (c 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38−7.35 (m, 2H), 7.31−7.23 (m, 3H), 5.70 (d, J = 11.2 Hz, 1H), 3.33 (dd, J = 3.3, 7.5 Hz, 1H), 3.21 (s, 3H), 3.08 (d, A part of AB, J_{AB} = 10.8 Hz, 1H), 2.91 (dd, J = 0.7, 11.4 Hz, 1H), 2.56 (dt, J = 3.7, 11.1 Hz, 1H), 2.43 (t, J = 10.9 Hz, 1H), 2.20−2.03 (m, 3H), 2.17 (d, B part of AB, J_{AB} = 10.8 Hz, 1H), 1.86−1.81 (m, 1H), 1.75 (dq, J = 3.7, 12.8 Hz, 1H), 1.71−1.60 (m, 2H), 1.58−1.52 (m, 1H), 1.55 (s, 9H), 1.50−1.43 (m, 1H), 1.41 (s, 9H), 1.36−1.17 (m, 4H), 1.13 (s, 9H), 1.02−0.96 (m, 1H), 0.99 (s, 3H), 0.91−0.84 (m, 1H), 0.81 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 174.0, 171.1, 152.6, 139.2, 128.2, 128.1 (2C), 127.9 (2C), 86.0, 81.9, 80.5, 79.9, 77.1, 60.6, 56.6, 55.9, 53.6, 52.8, 46.5, 45.7, 44.9, 41.5, 37.4, 32.0, 31.4, 28.3 (3C), 27.8 (3C), 27.6 (3C), 27.1, 26.6, 24.4, 20.6, 20.5; IR ($CHCl_3$) 3030, 2936, 1732, 1717, 1458, 1369, 1277, 1153, 1097 cm^{-1}; MS (20 eV) m/z 685 (M^+, 1), 568 (4), 478 (7), 364 (7), 222 (8), 182 (13), 107 (10), 57 (100); HRMS calcd for $C_{40}H_{63}NO_8$ (M^+) 685.4553, found 685.4549. Anal. Calcd for $C_{40}H_{63}NO_8$: C, 70.04; H, 9.26; N, 2.04. Found: C, 70.17; H, 9.19; N, 2.06.

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Supporting Information Available: ^{1}H NMR and ^{13}C NMR spectra for all new compounds, ORTEPs for **5a**, **6a**, **8b**, and **12**, and complete experimental details following the general procedures. This material is available free of charge via the Internet at http://pubs.acs.org.