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Stereoselective Synthesis of 2,6-*Cis*-Substituted Tetrahydropyrans: Brønsted Acid-Catalyzed Intramolecular Oxa-Conjugate Cyclization of α,β-Unsaturated Ester Surrogates

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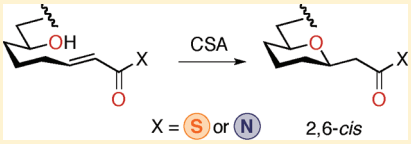
Supporting Information

ABSTRACT: Intramolecular oxa-conjugate cyclization (IOCC) of α,β-unsaturated carbonyl compounds, triggered by deprotonation with a base, represents a straightforward method for the synthesis of tetrahydropyrans. However, it has been known that stereochemical outcome of IOCC depends on the local structure of substrates and sometimes requires harsh reaction conditions and/or prolonged reaction times for selective formation of 2,6-*cis*-substituted tetrahydropyrans. These shortcomings limit the feasibility of IOCC in the context of complex natural product synthesis. In this paper, we describe Brønsted acid-catalyzed IOCC of α,β-unsaturated ester surrogates (e.g., α,β-unsaturated thioesters, oxazolidinone imides, and pyrrole amides) under mild reaction conditions, which affords a series of synthetically versatile 2,6-*cis*-substituted tetrahydropyran derivatives with good to excellent stereoselectivity (dr from 7:1 to >20:1). These α,β-unsaturated carbonyl compounds were found to be more reactive than the corresponding oxoesters that are generally unreactive toward Brønsted acid-catalyzed intramolecular oxa-conjugate additions. The product tetrahydropyrans could be transformed into various derivatives in an efficient manner, highlighting the usefulness of our methodology.

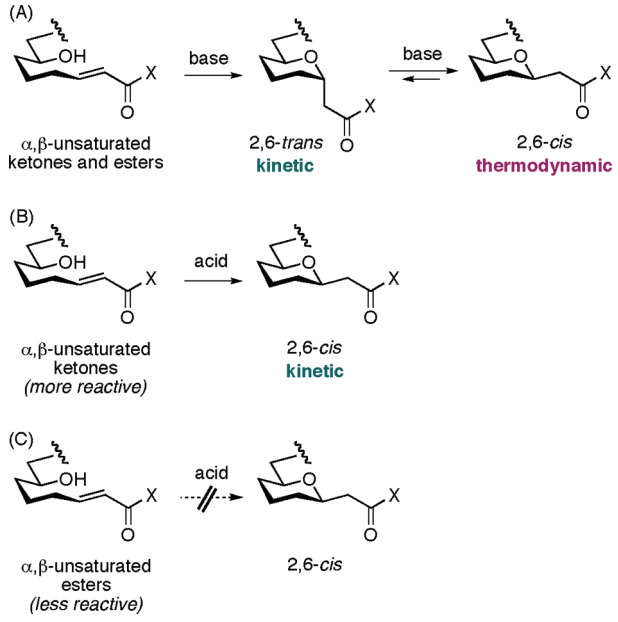


INTRODUCTION

There are a growing number of tetrahydropyran-containing marine natural substances that show potent and diverse biological activities.[1] Their importance at the interface of chemistry and biology is obvious as they serve as intriguing medicinal leads as well as powerful molecular probes for dissecting biological phenomena at the molecular level. As such, significant efforts have been devoted to development of efficient methodologies and tactics for the synthesis of tetrahydropyran derivatives.[2]

A number of methodologies are currently available for tetrahydropyran synthesis, e.g., intramolecular oxa-conjugate cyclization (IOCC),[3−7] Prins-type reaction,[8] modified Maitland−Japp reaction,[9] palladium-catalyzed intramolecular alkoxycarbonylation,[10] and palladium-catalyzed intramolecular S_N2' cyclization.[11,12] Among these, IOCC of α,β-unsaturated ketones and esters has served as key transformations in a number of total syntheses of complex natural products and related compounds due to the synthetic versatility of the product tetrahydropyrans.[5,6] The cyclization proceeds under basic conditions to provide, in most cases, 2,6-*trans*-substituted tetrahydropyrans as the kinetic product, and the corresponding 2,6-*cis* isomers can be obtained via a base-catalyzed ring-opening/recyclization sequence (Scheme 1A).[13,14] It should be noted that the majority of tetrahydropyrans found in naturally occurring substances have 2,6-*cis* stereochemistry. Nevertheless, stereoselective formation of 2,6-*cis*-substituted tetrahydropyrans is in some cases difficult to achieve even under thermodynamic conditions.[15] It appears that this is particularly true when α,β-unsaturated esters were employed as substrates, probably because the α-hydrogens of esters are less acidic than those of ketones. The difficulty in controlling stereoselectivity limits the usefulness of IOCC in tetrahydropyran synthesis. A complementary means to catalyze IOCC is the activation of

Scheme 1. Intramolecular Oxa-Conjugate Cyclization of α,β-Unsaturated Ketones/Esters



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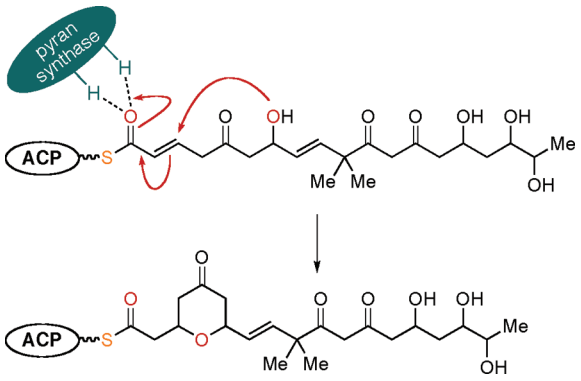
the conjugate acceptor by acids. It has been known that α,β-unsaturated ketones also participate in IOCC under acid catalysis to give 2,6-*cis*-substituted tetrahydropyrans (Scheme 1B),[16] but intrinsically less reactive α,β-unsaturated esters generally do not (Scheme 1C).[17]

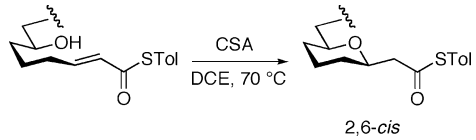
Recent studies on the biosynthesis of several tetrahydropyran-containing polyketides, such as pederin, ambruticin, bryostatins, jerangolid, and sorangicin, have suggested that the tetrahydropyrans embedded within the structures of those natural products would be forged via IOCC of α,β-unsaturated thioesters.[18] Illustrated in Scheme 2 is the postulated

Scheme 2. Proposed Biosynthesis of 2,6-Substituted Tetrahydropyrans of Polyketide Natural Products



biosynthetic formation of the bryostatin tetrahydropyran ring, according to Haygood and co-workers.[18b] They proposed that the tetrahydropyran ring would be formed during polyketide synthesis via IOCC of the intermediary acyl carrier protein (ACP)-bounded α,β-unsaturated thioester by the action of "pyran synthase". It seems that the cyclization would be facilitated by the activation of the carbonyl group of the α,β-unsaturated thioester, presumably through hydrogen bonding(s). We thought that the feasibility of the biosynthetic formation of tetrahydropyrans would be, at least in part, due to the enhanced reactivity of α,β-unsaturated thioesters.[19] Inspired by the biosynthetic proposal, we have recently reported on IOCC of α,β-unsaturated thioesters under Brønsted acid catalysis, which gives access to 2,6-*cis*-substituted tetrahydropyrans with high stereocontrol (Scheme 3;

Scheme 3. Brønsted Acid Catalyzed IOCC of α,β-Unsaturated Thioesters



Tol = *p*-tolyl).[20,21] It is significant that acid-catalyzed IOCC of α,β-unsaturated thioesters predominantly leads to synthetically useful 2,6-*cis*-substituted tetrahydropyrans. Furthermore, the products can be easily transformed into a variety of derivatives by exploiting the unique reactivity of the thioester functionality. However, the acid-catalyzed cyclization under high temperature conditions is imcompatible with sensitive substrates. To address the shortcoming of our methodology, we strove to seek for α,β-unsaturated ester surrogates with sufficiently high reactivity that enable Brønsted acid-catalyzed IOCC under room temperature conditions. In this paper, we detail our investigations into Brønsted acid-catalyzed IOCC of α,β-unsaturated ester surrogates for stereoselective synthesis of 2,6-*cis*-substituted tetrahydropyrans.

RESULTS AND DISCUSSION

Brønsted Acid-Catalyzed IOCC of α,β-Unsaturated Thioesters. To probe the reactivity of α,β-unsaturated thioesters toward IOCC under acid catalysis, we first prepared a series of thioesters from olefin (±)-**1** via an olefin cross-metathesis (CM) reaction,[22] as reported by Feringa and co-workers[23] (Table 1). Thus, olefin (±)-**1**, prepared from 3-(4-methoxybenzyloxy)propanal (4-pentenylmagnesium bromide, THF, 0 °C, 78%), was coupled with an appropriate thioacrylate by the action of the second-generation Hoveyda–Grubbs catalyst (**HG-II**)[24] in CH_2Cl_2 at 35 °C, giving rise to α,β-unsaturated thioesters **2a–f** in good yields with high *E*/*Z* selectivity (*E*/*Z* > 20:1 by 600 MHz ^{1}H NMR analysis).

We next examined IOCC of α,β-unsaturated thioesters **2a-f** (Table 1). Our preliminary experiments on IOCC of α,β-unsaturated *S*-ethyl thioester (±)-**2a** in the presence of various acids showed that Brønsted acids including *p*-TsOH·H_2O, (+)-10-camphorsulfonic acid (CSA), CH_3SO_3H, and CF_3CO_2H promoted the cyclization and that CSA was found to be the acid of choice. On the other hand, Lewis acids, such as $MgBr_2$, $InCl_3$, $Sc(OTf)_3$, $Zn(OTf)_2$, $Cu(OTf)_2$, and $Yb(OTf)_3$, are uniformly ineffective and resulted only in no reaction or material decomposition.[25] Accordingly, IOCC of α,β-unsaturated thioesters **2b-f** was examined by using CSA as a catalyst. In all cases, the cyclization had to be performed at room temperature and stopped before reaching to completion due to partial cleavage of the MPM ether as a side reaction. Nonetheless, information on the reactivity of α,β-unsaturated thioesters could be sufficiently gathered. Clearly, *S*-ethyl thioester (±)-**2a** (entry 1) was less reactive than *S*-aryl thioesters **2b-f** (entries 2–6). In addition, the presence of an electron-donating substituent at the para position of the benzene ring was beneficial for increasing the reactivity (entries 3 and 4), while *p*-nitro group was obviously detrimental (entry 5). For each product, the stereochemistry was determined on the basis of an NOE enhancement observed between two axial hydrogen atoms flanking the ether oxygen atom. Since (±)-**2c** displayed the highest reactivity among others, further investigations were carried out using *S*-(*p*-tolyl) thioesters.

To probe the scope of Brønsted acid-catalyzed IOCC, a variety of olefins were prepared as the precursors of α,β-unsaturated thioesters (Table 2 and Scheme 4). Olefin (±)-**4** was prepared from 3-(*tert*-butyldiphenylsilyloxy)propanal in 69% yield by reacting with 4-pentenylmagnesium bromide. Olefins (−)-**5**, (−)-**6**, (+)-**7**, and (+)-**8** are the known compounds.[6e,26] The preparation of olefins (+)-**9** and (+)-**10** started with the known alcohol (+)-**11**,[27] which was oxidized and then reacted with allylmagnesium bromide to give a separable mixture of homoallylic alcohols (+)-**12** and (+)-**13**, and these products were individually desilylated to deliver olefins (+)-**9** and (+)-**10**.

A series of α,β-unsaturated thioesters **14–20** were synthesized uneventfully by means of CM (Table 2). The cyclization of (±)-**14** proceeded only sluggishly in CH_2Cl_2 at room temperature (78% conversion after 40 h) and gave 2,6-*cis*-substituted tetrahydropyran (±)-**21** in 66% yield with greater than 20:1 diastereoselectivity. Gratifyingly, the reaction could be completed within 30 h by performing in 1,2-dichloroethane

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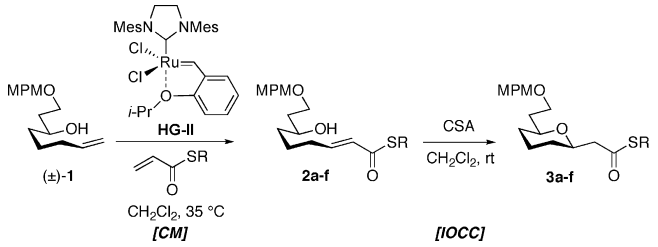
Table 1. Preparation and IOCC of α,β-Unsaturated Thioesters



		CM[a]	IOCC[b]		
entry	R	yield (%)	time (h)	yield (rsm[c]) (%)	*cis*/*trans*[d]
1[e]	Et	(±)-**2a**: 93	21	(±)-**3a**: 43 (26)	15:1
2	Ph	(±)-**2b**: 94	40	(±)-**3b**: 56 (41)	>20:1
3	*p*-MeC_6H_4	(±)-**2c**: 92	40	(±)-**3c**: 72 (12)	>20:1
4	*p*-$MeOC_6H_4$	(±)-**2d**: 82	44	(±)-**3d**: 69 (16)	>20:1
5	*p*-$NO_2C_6H_4$	(±)-**2e**: 94	45	(±)-**3e**: 29 (65)	>20:1
6	1-naphthyl	(±)-**2f**: 87	73	(±)-**3f**: 56 (35)	>20:1

[a]CM reactions were performed using **HG-II** (10 mol %) and thioacrylate (3 equiv) in CH_2Cl_2 at 35 °C. [b]IOCCs were performed using CSA (20 mol %) in CH_2Cl_2 at room temperature unless otherwise noted and quenched when cleavage of the *p*-methoxyphenylmethyl (MPM) ether was observed by TLC analysis. [c]rsm = recovered starting material. [d]Determined by 600 MHz ^{1}H NMR analysis. [e]IOCC was performed using 70 mol % of CSA.

(DCE) at 70 °C, giving tetrahydropyran (±)-**21** in 88% yield (entry 1). In a similar manner, IOCC of α,β-unsaturated thioesters **15**–**20** was performed by treatment with CSA (20 mol %) in DCE at 70 °C to provide the respective 2,6-*cis*-substituted tetrahydropyrans **22**–**27** in excellent yields with high diastereoselectivity (from 14:1 to >20:1) (entries 2–7). The stereochemistry of the cyclization products was established on the basis of NOE experiments and/or $^3J_{H,H}$ analysis (see Supporting Information for details). The cyclization of δ-substituted α,β-unsaturated thioesters [i.e., (−)-**15**, (−)-**16**, (+)-**17**, (+)-**19**, and (−)-**20**] proceeded more rapidly than that of unsubstituted ones [i.e., (±)-**14** and (+)-**18**]. It is likely that the conformation of δ-substituted α,β-unsaturated thioesters would avoid unfavorable steric repulsions between the bulky δ-substituent and the carbon chain as much as possible, thereby bringing the hydroxy group in close proximity to the α,β-unsaturated thioester group.

As shown above, Brønsted acid-catalyzed IOCC of α,β-unsaturated thioesters provides synthetically useful 2,6-*cis*-substituted tetrahydropyran derivatives in a highly stereoselective fashion. However, from a practical point of view, the cyclization has to be performed under elevated temperature conditions, making it difficult to apply to acid-sensitive substrates. To broaden the scope of our methodology, we strove to investigate additional α,β-unsaturated ester surrogates that exhibit enhanced reactivity toward IOCC.

Brønsted Acid-Catalyzed IOCC of α,β-Unsaturated Amides/Imides. Among the possible α,β-unsaturated ester equivalents, we chose to examine amide and imide derivatives due to their ready availability and ease of subsequent transformation.[28] A variety of α,β-unsaturated amides/imides **28a**–**g** were readily prepared via CM, as summarized in Table 3. Olefin (±)-**4** was coupled with an appropriate acryloyl amide/imide by the action of **HG-II** (5–10 mol %) in CH_2Cl_2 at 35 °C to provide **28a**–**g** in good to excellent yields with high *E*/*Z* selectivity (*E*/*Z* > 20:1).

We next investigated Brønsted acid-catalyzed IOCC of **28a**–**g** (Table 3). Cyclization of amide (±)-**28a** did not take place at all in the presence of CSA in CH_2Cl_2 at room temperature (entry 1). This result was not unanticipated because the low reactivity of simple α,β-unsaturated amides toward conjugate additions is well documented.[29] By contrast, imide (±)-**28b** underwent cyclization to afford 2,6-*cis*-substituted tetrahydropyran (±)-**29b** in 94% yield with moderate diastereoselectivity (dr 8:1, estimated by ^{1}H NMR analysis), indicating the importance of the electron-withdrawing carbonyl group of the pyrrolidine ring (entry 2). A slight improvement of stereoselectivity was observed upon changing the nitrogen heterocycle to oxazolidinone (entry 3). Thus, acid treatment of 2-oxazolidinone imide (±)-**28c** led to tetrahydropyran (±)-**29c** in 94% yield with satisfactory diastereoselectivity (dr 13:1). Cyclization of 2-benzoxazolidinone imide (±)-**28d** gave tetrahydropyran (±)-**29d** in a highly stereoselective manner (dr >20:1), although the reaction did not complete even after 40 h (entry 4). Indole amide (±)-**28e** showed good reactivity toward cyclization and provided tetrahydropyran (±)-**29e** in 90% yield (93% conversion) after 25 h with 15:1 diastereoselectivity (entry 5). On the other hand, indoline amide (±)-**28f** was much less reactive than (±)-**28e**, giving tetrahydropyran (±)-**29f** in 49% yield (62% conversion) after 25 h (entry 6). Finally, we found that the cyclization of 2,5-dimethylpyrrole amide (±)-**28g** completed within 24 h at room temperature to deliver tetrahydropyran (±)-**29g** in 90% yield as a single diastereomer (entry 7). In each case, the stereochemistry of the major diastereomer of the cyclization product was determined on the basis of NOE enhancement observed between axial protons flanking the ether oxygen (see the Supporting Information for details). From the results summarized in Table 3, it seems that the reactivity of the substrates would be inversely correlated with the electron-donating ability of the nitrogen lone pair toward the conjugate acceptor[30] and that α,β-unsaturated 2-oxazolidinone imides and 2,5-dimethylpyrrole amides[31] would be suitable candidates for Brønsted acid-catalyzed IOCC in terms of their reactivity and stereoselectivity.

To investigate the substrate scope, we synthesized a series of α,β-unsaturated 2-oxazolidinone imides and 2,5-dimethylpyrrole amides as summarized in Table 4. CM of olefins **1**, **5**–**7**, **9**, and **10** with 3-(2-propenoyl)-2-oxazolidinone in the presence of

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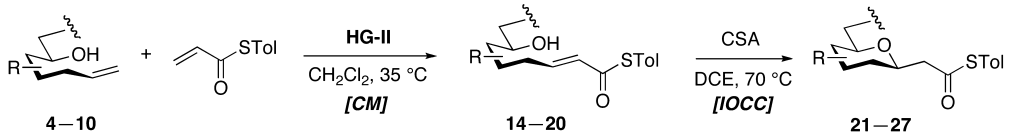
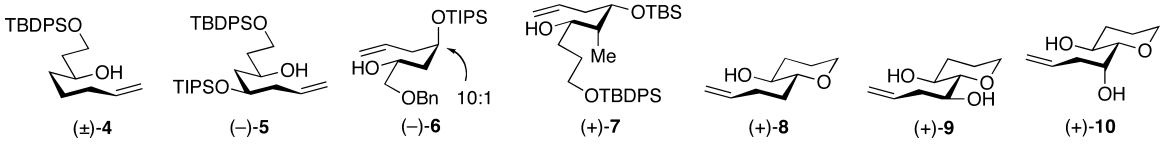
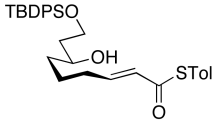
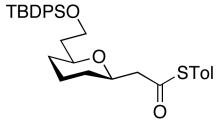
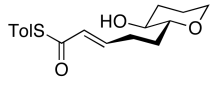
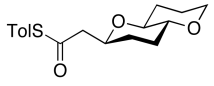
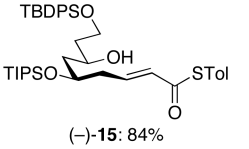
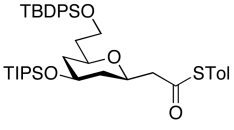
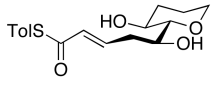
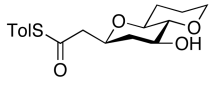
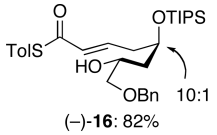
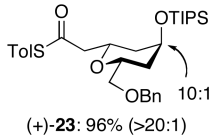
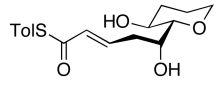
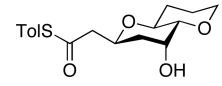
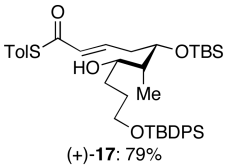
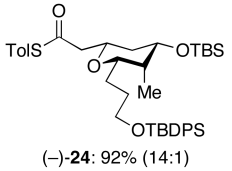
Table 2. Substrate Scope



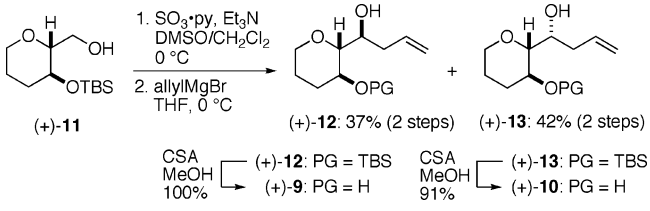
Olefins:



		CM[a]	IOCC[b]			CM[a]	IOCC[b]
Entry	Olefin	Product	Product (*cis*/*trans*[c])	Entry	Olefin	Product	Product (*cis*/*trans*[c])
1	(±)-**4**	 (±)-**14**: 90%	 (±)-**21**: 88% (>20:1)	5	(+)-**8**	 (+)-**18**: 93%	 (+)-**25**: 92% (>20:1)
2	(−)-**5**	 (−)-**15**: 84%	 (−)-**22**: 90% (>20:1)	6	(+)-**9**	 (+)-**19**: 94%	 (+)-**26**: 91% (>20:1)
3	(−)-**6**	 (−)-**16**: 82%	 (+)-**23**: 96% (>20:1)	7	(+)-**10**	 (−)-**20**: 82%	 (+)-**27**: 97% (>20:1)
4	(+)-**7**	 (+)-**17**: 79%	 (−)-**24**: 92% (14:1)				

[a]CM reactions were performed using **HG-II** (10 mol %) and thioacrylate (3 equiv) in CH_2Cl_2 at 35 °C. [b]IOCCs were performed using CSA (20 mol %) in DCE at 70 °C. For reaction time, see the Experimental Section. [c]Determined by 600 MHz ^{1}H NMR analysis.

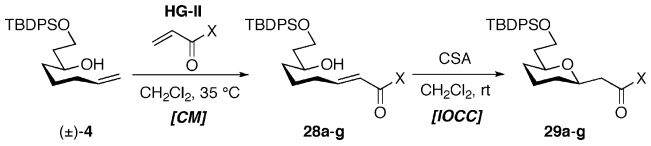
Scheme 4. Synthesis of Olefins (+)-9 and (+)-10

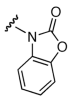


HG-II afforded the respective α,β-unsaturated 2-oxazolidinone imides **30**−**35** in high yields (entries 1−6). In a similar manner, α,β-unsaturated 2,5-dimethylpyrrole amides **36**−**42** were prepared from **1** and **5**−**10** via CM (entries 7−13), although their yields were uniformly lower than those of oxazolidinone derivatives. Next, Brønsted acid-catalyzed cyclization of α,β-unsaturated 2-oxazolidinone imides was examined (Table 4). Treatment of (±)-**30** with 20 mol % of CSA in CH_2Cl_2 at room temperature for 23 h gave 2,6-*cis*-substituted tetrahydropyran (±)-**43** in 86% yield with 14:1 diastereoselectivity (entry 1). Importantly, the IOCC of the corresponding α,β-unsaturated thioesters under the same reaction conditions proceeded quite sluggishly and resulted in lower product yields due to partial cleavage of the MPM ether as a side reaction (see Table 1). Cyclization of a series of α,β-unsaturated 2-oxazolidinone imides **31**−**35** in the presence of 20 mol % of CSA in CH_2Cl_2 at room temperature completed within reasonable reaction times to provide the corresponding 2,6-*cis*-substituted tetrahydropyrans **44**−**48** in excellent yields with a synthetically useful level of diastereoselectivity (dr from 9:1 to >20:1) (entries 2−6). Moreover, α,β-unsaturated 2,5-dimethylpyrrole amides **36**−**42** underwent clean cyclization upon exposure to 20 mol % of CSA (CH_2Cl_2, room temperature), giving rise to 2,6-*cis*-substituted tetrahydropyrans **49**−**55**, respectively, in high yields (entries 7−13). Most notably, all the products were isolated as single diastereomers (dr >20:1) except for (−)-**52** (entry 10). The olefin geometry of **40**, used as a 6:1 mixture of *E*/*Z* isomers, did not affect the diastereoselectivity of the cyclization, since

dx.doi.org/10.1021/jo202179s | J. Org. Chem. 2012, 77, 2588−2607

Table 3. Preparation and IOCC of α,β-Unsaturated Amides/Imides



		CM[a]		IOCC[b]	
Entry	X	Product	Time/h	Product	*cis*/*trans*[c]
1		(±)-**28a**: 96%	25	(±)-**29a**: 0%[d]	N/A[e]
2		(±)-**28b**: 72%	6.5	(±)-**29b**: 94%	8:1
3		(±)-**28c**: 86%	26	(±)-**29c**: 94%	13:1
4		(±)-**28d**: 91%	40	(±)-**29d**: 66%[f]	>20:1
5		(±)-**28e**: 85%	25	(±)-**29e**: 90%[g]	15:1
6		(±)-**28f**: 76%	25	(±)-**29f**: 49%[h]	10:1
7		(±)-**28g**: 76%	24	(±)-**29g**: 90%	>20:1

[a]CM reactions were performed using **HG-II** (5−10 mol %) in CH_2Cl_2 at 35 °C. [b]IOCCs were performed using CSA (20 mol %) in CH_2Cl_2 at room temperature. Reaction times were not optimized. [c]Determined by 600 MHz ^{1}H NMR analysis. [d](±)-**28a** was recovered in 92% yield. [e]Not applicable. [f](±)-**28d** was recovered in 17% yield. [g](±)-**28e** was recovered in 7% yield. [h](±)-**28f** was recovered in 38% yield.

its acid treatment provided **53** in 93% yield as a single stereoisomer (entry 11). It is clear from these results that α,β-unsaturated 2-oxazolidinone imides and 2,5-dimethylpyrrole amides exhibit much higher reactivity than the corresponding thioesters and give 2,6-*cis*-substituted tetrahydropyrans in a highly stereoselective fashion.

Brønsted Base-Catalyzed IOCC of α,β-Unsaturated Ester Surrogates. Having investigated the reactivity of α,β-unsaturated ester surrogates toward Brønsted acid-catalyzed IOCC, we briefly examined Brønsted base-catalyzed IOCC of α,β-unsaturated thioester (+)-**17** and 2,5-dimethylpyrrole amide (+)-**39** (Table 5). As a control experiment, α,β-unsaturated ester (+)-**56** was treated with KO*t*-Bu (20 mol %) in THF at −78 °C to give 2,6-*trans*-substituted tetrahydropyran (−)-*trans*-**57** in 81% yield with good diastereoselectivity (dr 4:1) (entry 1). IOCC of (+)-**17** under the identical conditions afforded (−)-*trans*-**24** in 85% yield, and the observed diastereoselectivity was exactly the same as that of the corresponding oxoester (+)-**56** (entry 2). Thus, the stereoselectivity of base-catalyzed IOCC of α,β-unsaturated thioesters may be similar to that of α,β-unsaturated esters. On the other hand, cyclization of (+)-**39** under the same conditions as those used for (+)-**17** and (+)-**56** gave tetrahydropyran (−)-**52** as a 1:1 mixture of diastereomers (entry 3). In this case, it is likely that thermodynamic equilibration between 2,6-*cis* and 2,6-*trans* isomers occurred even under the low temperature conditions, due to the high acidity of the α-hydrogens of pyrrole amides. Indeed, exposure of (−)-*trans*-**52** to the cyclization conditions (KO*t*-Bu, THF, −78 °C) gave an approximately 1:1 mixture of 2,6-*cis* and 2,6-*trans* isomers.

Stereoselectivity of IOCC of (*E*)-α,β-Unsaturated Ester Surrogates. It has been known that Brønsted base-catalyzed IOCC of (*E*)-α,β-unsaturated esters provides 2,6-*trans*-substituted tetrahydropyrans under kinetic conditions.[32] On the basis of theoretical and experimental studies, Martín and co-workers[13b,c] have proposed a chelate-controlled model to account for the selective formation of 2,6-*trans* isomers. Schneider and Schuffenhauer have shown that IOCC of (*E*)-α,β-unsaturated oxazolidinone imides catalyzed by KO*t*-Bu provided 2,6-*trans*-substituted tetrahydropyrans in a stereoselective fashion. Supported by semiempirical molecular orbital calculations, they reasoned the observed stereoselectivity by a stereoelectronic effect.[13e,33] Coupled with our results summarized in Table 5, the Martín's chelate-controlled transition structure model would also be viable for understanding the stereoselectivity of Brønsted base-catalyzed kinetic cyclization of (*E*)-α,β-unsaturated ester surrogates (Scheme 5A). Thus, in transition state B (**TS-B**), chelation of the potassium cation between the alkoxide and the conjugate acceptor is well accommodated, whereas in **TS-A**, the conjugate acceptor has to adopt energetically unfavorable *s-trans* conformation[34] to accommodate the chelation.[13c] Moreover, according to the theoretical calculations by the Martín and Schneider groups,[13c,e] the attack angle ∠(O−C(β)=C(α)) of **TS-B** would be nearly tetrahedral (the Bürgi−Dunitz trajectory) so as to maximize stabilizing HOMO/LUMO interaction, while the attack angle of **TS-A** would be smaller than that of **TS-B** (around 100°).[35] Accordingly, **TS-B** would be energetically preferred over **TS-A**.

Houk and Strozier have shown that protonation of acrolein results in significant changes in the energy levels and coefficients of the frontier molecular orbitals (FMO). Thus, the FMO of protonated acrolein are more like "those of an allylic cation mixed with a lone-pair orbital on oxygen".[36] In line with the theoretical study by Houk and Strozier, it has been proposed that acid-catalyzed hydration of aliphatic α,β-unsaturated ketones **I**, such as 3-buten-2-one derivatives, involves protonation of the carbonyl oxygen followed by addition of H_2O to the β-carbon atom (Scheme 6). Because of the contribution of the canonical structures **II** and **III**, the transition structure of the reaction would have an allylic cationic character.[37] On the basis of these previous studies, we propose that Brønsted acid-catalyzed IOCC of (*E*)-α,β-unsaturated ester surrogates would involve an allylic cationic transition structure[38] and proceed via an S_N1-type mechanism (Scheme 5B). In this context, two possible chairlike **TS-C** and **TS-D** could be considered, and their conformation would be basically similar to that of **TS-A** and **TS-B**, respectively. **TS-D** suffers from the 1,3-diaxial interactions as shown, while such an unfavorable steric repulsion does not exist in **TS-C**. Moreover, in contrast to the arguments on **TS-A**/**TS-B**, the stabilizing HOMO/LUMO interaction in **TS-C** would be greater than that in **TS-D** by considering the attack angle and the coefficients of the LUMO. Thus, **TS-C** would be energetically favored over **TS-D** by both steric and stereoelectronic reasons. This transition state model well explains the observed stereoselectivity of the cyclization.[39]

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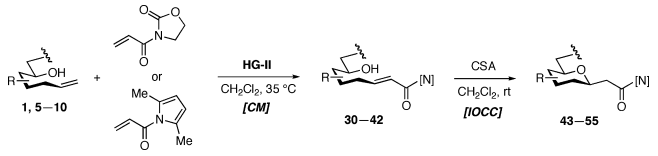
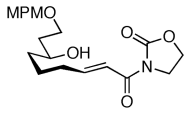
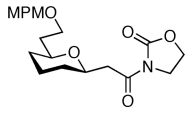
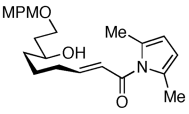
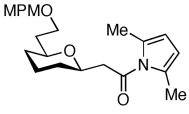
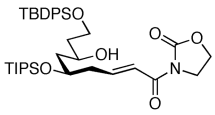
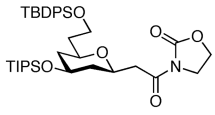
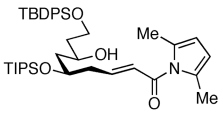
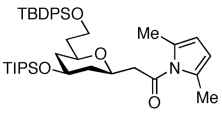
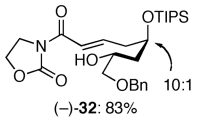
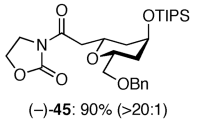
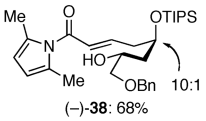
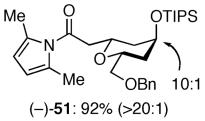
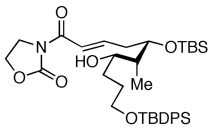
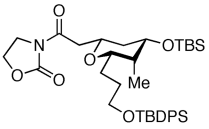
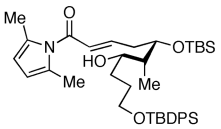
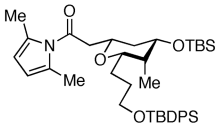
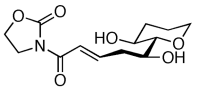
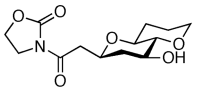
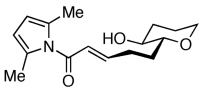
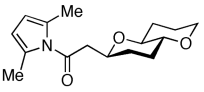
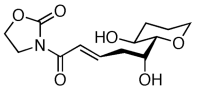
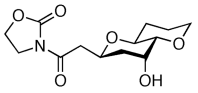
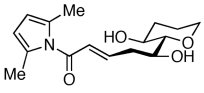
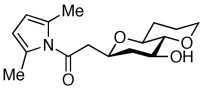
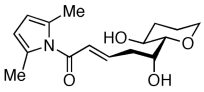
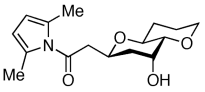
Table 4. Application to a Variety of Substrates



		CM[a]	IOCC[b]			CM[a]	IOCC[b]
Entry	Olefin	Product	Product (*cis*/*trans*[c])	Entry	Olefin	Product	Product (*cis*/*trans*[c])
1	(±)-**1**	 (±)-**30**: 84%	 (±)-**43**: 86% (14:1)	7	(±)-**1**	 (±)-**36**: 66%	 (±)-**49**: 88% (>20:1)
2	(−)-**5**	 (−)-**31**: 81%	 (+)-**44**: 96% (9:1)	8	(−)-**5**	 (−)-**37**: 70%	 (+)-**50**: 91% (>20:1)
3	(−)-**6**	 (−)-**32**: 83%	 (−)-**45**: 90% (>20:1)	9	(−)-**6**	 (−)-**38**: 68%	 (−)-**51**: 92% (>20:1)
4	(+)-**7**	 (+)-**33**: 85%	 (−)-**46**: 88% (10:1)	10	(+)-**7**	 (+)-**39**: 68%	 (−)-**52**: 86% (7:1)
5	(+)-**9**	 (−)-**34**: 85%	 (+)-**47**: 83% (11:1)	11	(+)-**8**	 (+)-**40**: 68%[d]	 (−)-**53**: 93% (>20:1)
6	(+)-**10**	 (+)-**35**: 81%	 (−)-**48**: 86% (>20:1)	12	(+)-**9**	 (+)-**41**: 71%[e]	 (−)-**54**: 91% (>20:1)
				13	(+)-**10**	 (+)-**42**: 64%	 (−)-**55**: 93% (>20:1)

[a]CM reactions were performed using **HG-II** (10 mol %) in CH_2Cl_2 at 35 °C. [b]IOCCs were performed using CSA (20 mol %) in CH_2Cl_2 at room temperature. For reaction time (not optimized), see the Experimental Section. [c]Determined by 600 MHz ^{1}H NMR analysis. [d]Isolated as a 6:1 mixture of *E*/*Z* isomers. [e]Isolated as a 9:1 mixture of *E*/*Z* isomers.

Another important point of Brønsted acid-catalyzed IOCC of (*E*)-*α*,*β*-unsaturated ester surrogates is that the stereoselective formation of 2,6-*cis*-substituted tetrahydropyrans is kinetically controlled and is not a result of thermodynamic equilibration. We confirmed that resubjection of thermodynamically less stable (−)-*trans*-**24** to the cyclization conditions (20 mol % CSA, DCE, 70 °C, 6 h) did not induce any isomerization to thermodynamically more stable (−)-*cis*-**24** and resulted in almost quantitative (96%) recovery of (−)-*trans*-**24** (Scheme 7). Similarly, treatment of (±)-*trans*-**29c**[40] with CSA (20 mol %) in CH_2Cl_2 at room temperature for 24 h cleanly returned the starting material (95% recovery). We also confirmed that 2,5-dimethylpyrrole amide derivative (−)-*trans*-**52** did not isomerize to (−)-**52** under the cyclization conditions (CSA (20 mol %), CH_2Cl_2, room temperature, 8.5 h).

Reactivity of *α*,*β*-Unsaturated Ester Surrogates. Although *α*,*β*-unsaturated esters are generally unreactive toward IOCC under acidic conditions, we have shown that *α*,*β*-unsaturated thioesters, 2-oxazolidinone imides, and 2,5-dimethylpyrrole amides underwent Brønsted acid-catalyzed IOCC to provide 2,6-*cis*-substituted tetrahydropyran derivatives. The reactivity of *α*,*β*-unsaturated ester surrogates (−)-**15**, (−)-**31**, and (−)-**37** was compared by monitoring their cyclization by

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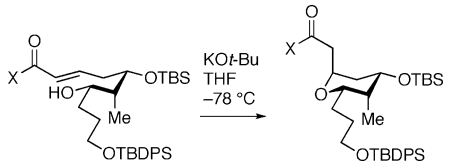
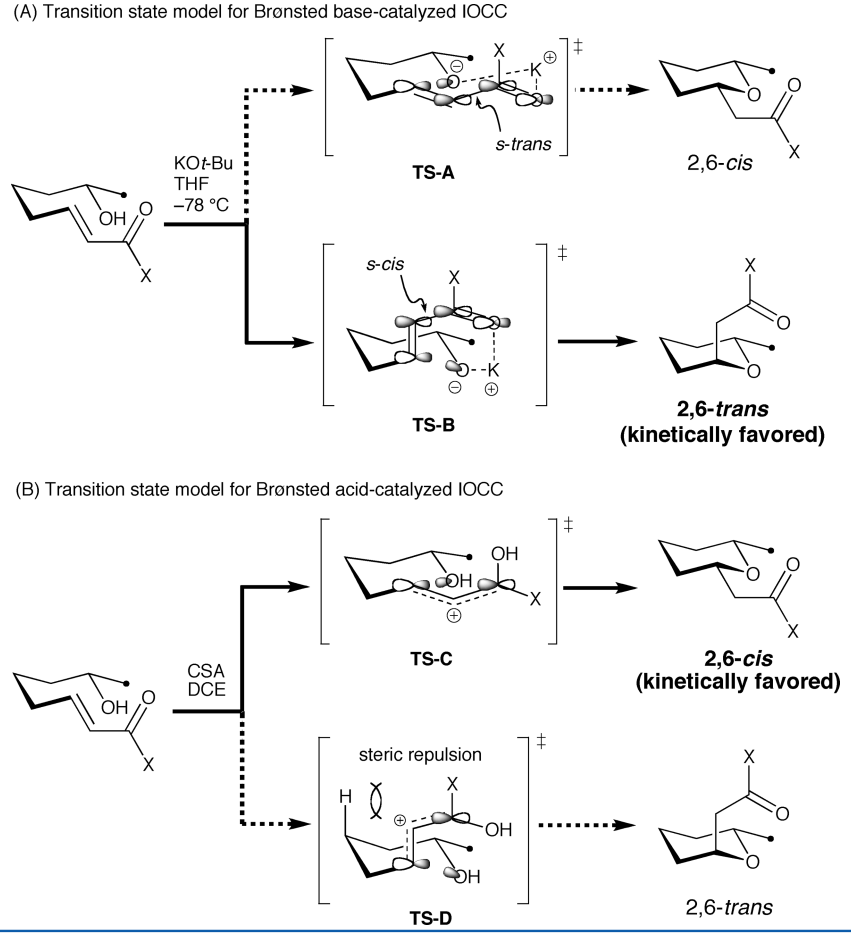
Table 5. Brønsted Base-Catalyzed IOCC of α,β-Unsaturated Ester and Its Surrogates[a]



entry	substrate	X	product	yield (%)	*trans*/*cis*[b]
1	(+)-**56**	OMe	(−)-*trans*-**57**	81	4:1
2	(+)-**17**	STol	(−)-*trans*-**24**	85	4:1
3	(+)-**39**	2,5-dimethylpyrrolyl	(−)-*trans*-**52**	92	1:1

[a]All reactions were performed using KO*t*-Bu (20−50 mol %) in THF at −78 °C. [b]Determined by 600 MHz ^{1}H NMR analysis of a purified mixture of diastereomers.

Scheme 5. (A) Transition-State Model for Brønsted Base-Catalyzed IOCC of (*E*)-α,β-Unsaturated Ester Surrogates. (B) Transition-State Model for Brønsted Acid-Catalyzed IOCC of (*E*)-α,β-Unsaturated Ester Surrogates



^{1}H NMR spectroscopy (20 mol % CSA, CD_2Cl_2, room temperature), and the results are depicted in Figure 1. Thus, we established that the reactivity order is: 2,5-dimethylpyrrole amide (−)-**37** > 2-oxazolidinone imide (−)-**31** > *S*-(*p*-tolyl) thioester (−)-**15**.

On the basis of our proposed reaction mechanism of Brønsted acid-catalyzed IOCC, the high reactivity of α,β-unsaturated ester surrogates (e.g., **15**, **31**, and **37**) could be reasoned by their propensity to form the corresponding allylic cationic intermediates upon protonation. It is well-known that aliphatic esters do not undergo keto−enol tautomerism easily, because the lone pair of the ester oxygen delocalizes to the carbonyl group and reduces the acidity of the α-hydrogens.[41] In contrast, acid-catalyzed keto−enol tautomerism of aliphatic thioesters, 2-oxazolidinone imides, and 2,5-dimethylpyrrole amides would be more facile than that of esters, due to the low electron donating ability of the sulfur or nitrogen atom and sufficient Lewis basicity of the carbonyl oxygen.[41] Analogously, protonation of α,β-unsaturated ester surrogates, such as **15**, **31**, and **37**, would easily generate the corresponding allylic cationic intermediates that subsequently react intramolecularly with the pendant hydroxy group, while such a reaction would be difficult to occur in the case of less reactive α,β-unsaturated esters.

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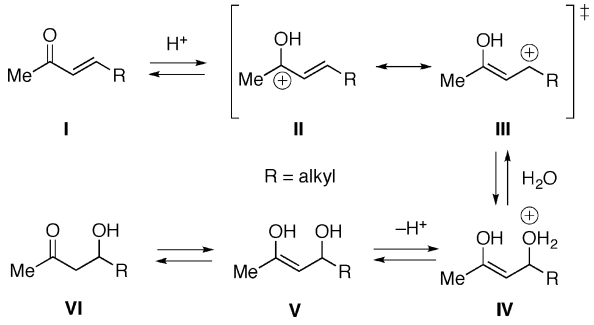
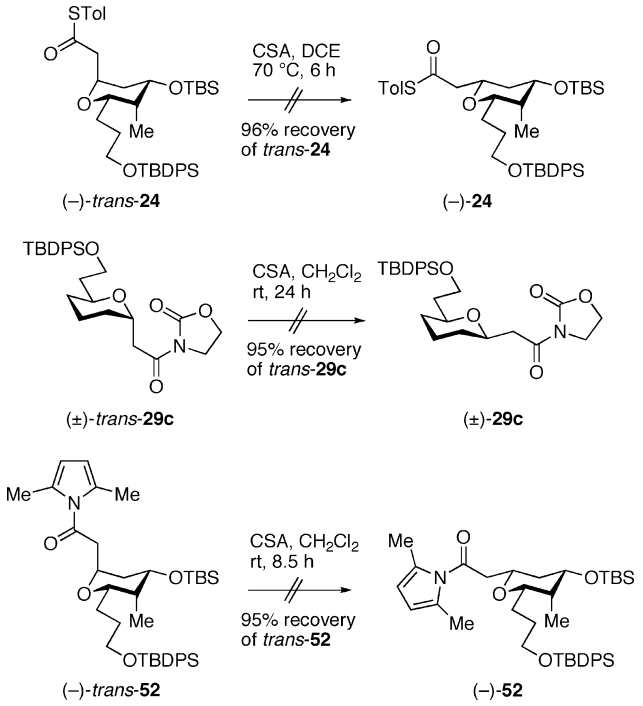
Scheme 6. Mechanism of Acid-Catalyzed Hydration of 3-Buten-2-one Derivatives



Scheme 7. Isomerization Experiments



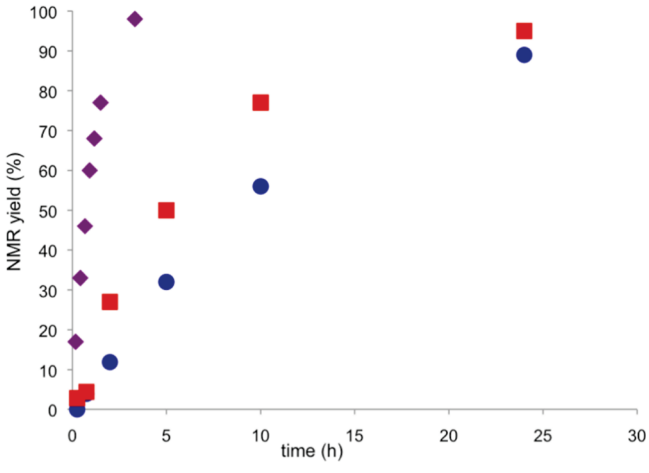
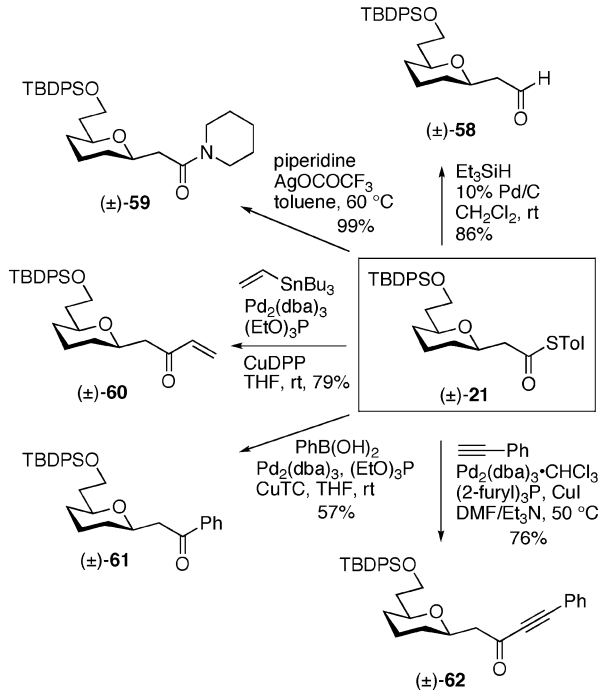
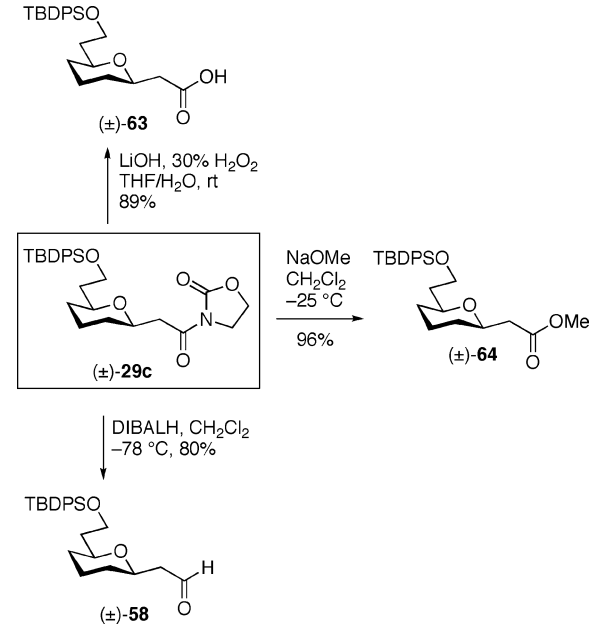


Figure 1. Comparison of reactivity of α,β-unsaturated thioester **15** (●), 2-oxazolidinone imide **31** (■), and 2,5-dimethylpyrrole amide **37** (◆) by ^{1}H NMR spectroscopy.

Scheme 8. One-Step Transformation of *S*-(*p*-Tolyl) Thioester (±)-21



Scheme 9. One-Step Transformation of 2-Oxazolidinone Imide (±)-29c



Transformation of the Product Tetrahydropyrans. Finally, we evaluated the synthetic versatility of the cyclization products (±)-**21**, (±)-**29c**, and (±)-**29g** (Schemes 8–10). It is well accepted that a diverse set of carbonyl compounds is available from thioesters in one step (Scheme 8). Fukuyama reduction[42] of (±)-**21** provided aldehyde (±)-**58** in 86% yield. Amidation of (±)-**21** could be efficiently performed in the presence of $AgOCOCF_3$[43] to give amide (±)-**59** in 99% yield. Moreover, thioester (±)-**21** is amenable to a series of palladium-catalyzed

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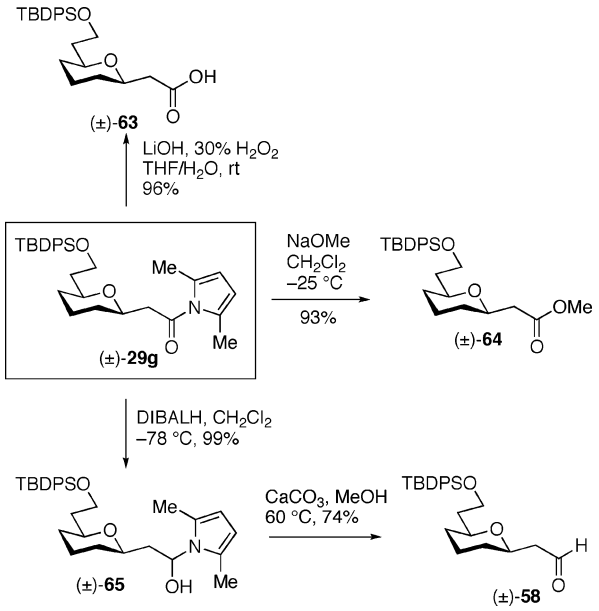
coupling reactions,[44−48] leading to asymmetric ketones (±)-**60**, (±)-**61**, and (±)-**62** in moderate to good yields.

Similarly, 2-oxazolidinone imide (±)-**29c** could be readily elaborated to the corresponding carboxylic acid (±)-**63**, ester (±)-**64** or aldehyde (±)-**58** in one step (Scheme 9).[49,50]

Transformation of 2,5-dimethylpyrrole amide (±)-**29g** to carboxylic acid (±)-**63** or ester (±)-**64** proceeded without incident (Scheme 10). On the other hand, DIBALH reduction

Scheme 10. Transformation of 2,5-Dimethylpyrrole Amide (±)-29g



of (±)-**29g** gave pyrrolyl carbinol (±)-**65** as a 1:1 mixture of diastereomers.[51] It was necessary to treat (±)-**65** with a catalytic amount of $CaCO_3$ in MeOH at 60 °C to obtain aldehyde (±)-**58** in good yield.

CONCLUSION

We have demonstrated that stereoselective synthesis of 2,6-*cis*-substituted tetrahydropyrans could be efficiently achieved by means of Brønsted acid-catalyzed IOCC of *α,β*-unsaturated ester surrogates. The cyclization precursor *α,β*-unsaturated ester surrogates were readily accessible via olefin cross-metathesis. A "biomimetic" IOCC of *α,β*-unsaturated thioesters under Brønsted acid catalysis was demonstrated to give access to 2,6-*cis*-substituted tetrahydropyrans in a highly stereoselective fashion, although elevated temperature conditions were required. Among the other *α,β*-unsaturated carboxylic acid derivatives examined, *α,β*-unsaturated 2-oxazolidinone imides and 2,5-dimethylpyrrole amides showed satisfactory reactivity toward Brønsted acid-catalyzed IOCC and afforded 2,6-*cis*-substituted tetrahydropyran derivatives in a synthetically useful level of diastereoselectivity. Because of the mild reaction conditions, our methodology would be applicable to a broad range of substrates. In addition, the product tetrahydropyrans could be easily transformed into various derivatives. The chemistry described in this paper would significantly broaden the scope of IOCC for tetrahydropyran synthesis. We believe that our methodology would find its use in the synthesis of complex tetrahydropyran-containing natural products.

EXPERIMENTAL SECTION

General Remarks. All reactions sensitive to moisture and/or air were carried out under an atmosphere of argon in dry, freshly distilled solvents under anhydrous conditions using oven-dried glassware unless otherwise noted. Commercially available anhydrous dichloromethane (CH_2Cl_2) was used directly without further drying. Anhydrous diethyl ether (Et_2O), tetrahydrofuran (THF), and toluene were purified by a Glass Contour solvent purification system under an atmosphere of argon immediately prior to use. 1,2-Dichloroethane (DCE) and triethylamine (Et_3N) were distilled from calcium hydride under an atmosphere of argon. *N,N*-dimethylformamide (DMF) was distilled from magnesium sulfate under reduced pressure. Degassed solvents were obtained by repeating freeze−thaw cycle for three times. All other chemicals were purchased at the highest commercial grade and used directly. ^1H and ^{13}C NMR spectra were recorded at 22 °C unless otherwise noted. Chemical shift values of ^1H and ^{13}C NMR spectra are reported in ppm (δ) downfield from tetramethylsilane with reference to internal solvent [^1H NMR, $CHCl_3$ (7.24), C_6HD_5 (7.15); ^{13}C NMR, $CDCl_3$ (77.0), C_6D_6 (128.0)] unless otherwise noted. Coupling constants (J) are reported in hertz (Hz). The following abbreviations were used to designate the multiplicities: s = singlet; d = doublet; t = triplet; m = multiplet; br = broad.

Olefin (±)-1. To a solution of 3-(4-methoxybenzyloxy)propanal[52] (4.80 g, 24.7 mmol) in THF (90 mL) at 0 °C was added a solution of 4-pentenylmagnesium bromide (ca. 1.0 M solution in THF, 33.8 mL, ca. 33.8 mmol), and the resultant mixture was stirred at 0 °C for 70 min. The reaction was quenched with saturated aqueous NH_4Cl solution. The resultant mixture was extracted with EtOAc, and the organic layer was washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (5−10% EtOAc/hexanes) gave olefin (±)-**1** (5.07 g, 78%) as a colorless oil: IR (film) 3436, 2935, 2859, 1613, 1514, 1460, 1248, 1092, 1036, 821 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.26−7.23 (m, 2H), 6.89−6.86 (m, 2H), 5.80 (dddd, J = 17.2, 8.9, 6.9, 6.5 Hz, 1H), 5.00 (dddd, J = 17.2, 2.1, 1.7, 1.7 Hz, 1H), 4.94 (dddd, J = 8.9, 2.1, 1.4, 1.4 Hz, 1H), 4.45 (s, 2H), 3.82−3.77 (m, 4H), 3.69 (ddd, J = 9.3, 5.2, 5.2 Hz, 1H), 3.61 (ddd, J = 9.3, 6.2, 6.2 Hz, 1H), 2.93 (br s, 1H), 2.11−2.02 (m, 2H), 1.74−1.70 (m, 2H), 1.57−1.39 (m, 4H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 159.2, 138.7, 129.9, 129.2 (2C), 114.4, 113.8 (2C), 72.9, 71.2, 68.9, 55.2, 36.8, 36.3, 33.7, 24.8; HRMS (ESI) calcd for $C_{16}H_{24}O_3Na$ [(M + Na)$^+$] 287.1618, found 287.1624.

Olefin (±)-4. Prepared in 69% yield from 3-(*tert*-butyldiphenylsilyloxy)propanal[53] in the same way as that described for (±)-**1**. Data for (±)-**4**: IR (film) 2914, 1357, 1314, 1275, 1102 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.72−7.62 (m, 4H), 7.45−7.32 (m, 6H), 5.80 (m, 1H), 5.00 (d, J = 17.2 Hz, 1H), 4.94 (d, J = 8.9 Hz, 1H), 3.90−3.78 (m, 3H), 3.24 (s, 1H), 2.08−2.04 (m, 2H), 1.73−1.62 (m, 2H), 1.58−1.38 (m, 4H), 1.03 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 138.8 (2C), 135.5 (2C), 134.8, 133.0, 132.9, 129.8 (2C), 129.5, 127.8 (2C), 127.6, 114.5, 71.7, 63.6, 38.3, 36.9, 33.7, 26.8 (3C), 24.8, 19.0; HRMS (ESI) calcd for $C_{24}H_{34}O_2SiNa$ [(M + Na)$^+$] 405.2220, found 405.2221.

Olefins (−)-5, (−)-6, (+)-7, and (+)-8. These compounds were previously prepared.[6e,26]

Olefins (+)-12 and (+)-13. To a solution of alcohol (+)-**11** (601.1 mg, 2.442 mmol) and Et_3N (1.35 mL, 9.74 mmol) in CH_2Cl_2/DMSO (1:1, v/v, 20 mL) at 0 °C were added SO_3·pyridine complex (1.17 g, 7.35 mmol), and the resultant mixture was stirred at 0 °C for 40 min. The reaction was quenched with H_2O, and the resultant mixture was diluted with Et_2O. The organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residual crude aldehyde was immediately used in the next reaction without further purification.

To a solution of the above material in THF (16 mL) at 0 °C were added allylmagnesium bromide (1.0 M solution in Et_2O, 4.90 mL, 4.90 mmol), and the resultant mixture was stirred at 0 °C for 50 min. The reaction was quenched with saturated aqueous NH_4Cl solution, and the resultant mixture was extracted with EtOAc. The organic layer was

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washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (5 to 10% Et_2O/hexanes) followed by preparative HPLC ($CHCl_3$) gave olefin (+)-**12** (258.1 mg, 37% for the two steps) as a colorless oil, along with olefin (+)-**13** (290.7 mg, 42% for the two steps) as a pale yellow oil. Data for (+)-**12**: $[\alpha]^{31}_D$ +38.1 (*c* 1.00, $CHCl_3$); IR (film) 3482, 2936, 2857, 1472, 1252, 1096, 837, 777 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 5.82 (dddd, *J* = 17.2, 10.0, 7.2, 6.9 Hz, 1H), 5.09 (dddd, *J* = 17.2, 2.0, 1.7, 1.7 Hz, 1H), 5.06 (dddd, *J* = 10.0, 2.0, 1.0, 1.0 Hz, 1H), 3.90 (dddd, *J* = 8.9, 4.1, 2.0, 1.4 Hz, 1H), 3.84 (m, 1H), 3.67 (ddd, *J* = 13.7, 8.9, 4.8 Hz, 1H), 3.32 (m, 1H), 2.93 (dd, *J* = 8.9, 1.4 Hz, 1H), 2.36 (m, 1H), 2.27 (m, 1H), 2.03 (m, 1H), 1.89 (d, *J* = 8.9 Hz, 1H), 1.65−1.58 (m, 2H), 1.41 (m, 1H), 0.86 (s, 9H), 0.08 (s, 3H), 0.06 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 135.4, 117.1, 82.7, 68.3, 67.8, 66.8, 38.9, 33.4, 25.8 (3C), 25.4, 17.9, −4.1, −4.9; HRMS (ESI) calcd for $C_{15}H_{30}O_3SiNa$ [(M + Na)$^+$] 309.1856, found 309.1861. Data for (+)-**13**: $[\alpha]^{30}_D$ +65.3 (*c* 1.00, $CHCl_3$); IR (film) 3502, 2930, 1472, 1254, 1098, 837, 776 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 5.90 (m, 1H), 5.12 (dddd, *J* = 17.2, 2.0, 1.4, 1.4 Hz, 1H), 5.08 (dddd, *J* = 10.3, 2.0, 1.0, 1.0 Hz, 1H), 3.92−3.84 (m, 2H), 3.53 (ddd, *J* = 10.6, 8.9, 4.4 Hz, 1H), 3.30 (m, 1H), 3.12 (dd, *J* = 8.9, 4.8 Hz, 1H), 2.75 (d, *J* = 5.2 Hz, 1H), 2.35 (m,1H), 2.23 (m, 1H), 2.02 (m, 1H), 1.65−1.60 (m, 2H), 1.65 (m, 1H), 0.86 (s, 9H), 0.080 (s, 3H), 0.076 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 135.5, 117.1, 83.8, 71.6, 70.8, 68.0, 36.1, 33.8, 25.7 (3C), 25.5, 17.9, −3.6, −4.8; HRMS (ESI) calcd for $C_{15}H_{30}O_3SiNa$ [(M + Na)$^+$] 309.1856, found 309.1860.

Olefin (+)-9. To a solution of olefin (+)-**12** (242.2 mg, 0.845 mmol) in MeOH (8 mL) was added CSA (39.3 mg, 0.169 mmol), and the resultant solution was stirred at room temperature for 6.5 h. The reaction was quenched with Et_3N, and the resultant mixture was concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (60% EtOAc/hexanes) gave olefin (+)-**9** (144.9 mg, 100%) as a colorless solid: mp 70.4−70.6 °C (EtOAc/hexanes); $[\alpha]^{25}_D$ +40.5 (*c* 1.00, $CHCl_3$); IR (film) 3339, 2938, 2855, 1430, 1098, 1058, 639 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 5.84 (dddd, *J* = 17.5, 10.3, 7.2, 7.2 Hz, 1H), 5.13 (m, 1H), 5.10 (m, 1H), 3.89−3.94 (m, 2H), 3.70 (dddd, *J* = 10.3, 9.2, 5.5, 4.5 Hz, 1H), 3.32 (m, 1H), 3.01 (dd, *J* = 9.2, 2.0 Hz, 1H), 2.38−2.32 (m, 2H), 2.26 (m, 1H), 2.14−2.09 (m, 2H), 1.68−1.62 (m, 2H), 1.42 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 135.1, 117.7, 82.4, 69.4, 67.8, 66.2, 38.1, 32.5, 25.4; HRMS (ESI) calcd for $C_9H_{16}O_3Na$ [(M + Na)$^+$] 195.0992, found 195.0994.

Olefin (+)-10. To a solution of olefin (+)-**13** (239.5 mg, 0.836 mmol) in MeOH (8 mL) was added CSA (38.8 mg, 0.167 mmol), and the resultant solution was stirred at room temperature for 6.5 h. The reaction was quenched with Et_3N, and the resultant mixture was concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (15% acetone/hexanes then 20% EtOAc/benzene) gave olefin (+)-**10** (130.9 mg, 91%) as a colorless oil: $[\alpha]^{31}_D$ +24.0 (*c* 1.00, $CHCl_3$); IR (film) 3365, 2940, 2856, 1436, 1097, 1031, 913, 591 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 5.82 (dddd, *J* = 16.9, 10.7, 8.2, 6.2 Hz, 1H), 5.21−5.15 (m, 2H), 3.88 (dddd, *J* = 11.3, 3.8, 2.0, 1.4 Hz, 1H), 3.75 (ddd, *J* = 8.2, 7.9, 2.7 Hz, 1H), 3.60 (ddd, *J* = 10.6, 8.3, 4.8 Hz, 1H), 3.50 (br s, 1H), 3.29 (m, 1H), 2.92 (dd, *J* = 8.3, 8.2 Hz, 1H), 2.60 (ddddd, *J* = 14.0, 6.2, 3.1, 1.4, 1.4 Hz, 1H), 2.41 (br s, 1H), 2.21 (ddd, *J* = 14.0, 8.6, 8.2 Hz, 1H), 2.11 (m, 1H), 1.67−1.62 (m, 2H), 1.41 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 134.2, 119.0, 81.9, 74.2, 70.8, 67.6, 38.4, 32.0, 25.1; HRMS (ESI) calcd for $C_9H_{16}O_3Na$ [(M + Na)$^+$] 195.0992, found 195.0998.

***α,β*-Unsaturated Thioesters 2a−f and 14−20.** *General Procedure for Olefin Cross-Metathesis Reaction (GP1).* To a solution of olefin (±)-**1** (341.7 mg, 1.29 mmol) and *S*-ethyl 2-propenthioate[54] (0.450 mL, 3.88 mmol) in CH_2Cl_2 (5 mL) was added a solution of the Hoveyda−Grubbs second-generation catalyst (32.3 mg, 0.0515 mmol) in CH_2Cl_2 (1.5 mL), and the resultant solution was stirred at 35 °C for 18 h. After complete consumption of **1**, the reaction mixture was cooled to room temperature and directly purified by flash chromatography on silica gel (10 to 20 to 30% EtOAc/hexanes) to give *α,β*-unsaturated thioester (±)-**2a** (421.4 mg, 93%) as a brown oil.

(±)-**2a**: IR (film) 3460, 2932, 2862, 1669, 1513, 1248, 1091, 1034, 820 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.23−7.21 (m, 2H), 6.88−6.83 (m, 3H), 6.08 (ddd, *J* = 15.9, 1.7, 1.7 Hz, 1H), 4.32 (s, 2H), 3.81−3.75 (m, 4H), 3.68 (m, 1H), 3.60 (m, 1H), 2.99 (br d, *J* = 2.4 Hz, 1H), 2.91 (q, *J* = 7.6 Hz, 2H), 2.22−2.17 (m, 2H), 1.74−1.67 (m, 2H), 1.61 (m, 1H), 1.53−1.38 (m, 3H), 1.25 (t, *J* = 7.6 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 190.1, 159.2, 144.9, 129.9, 129.3 (2C), 128.8, 113.8 (2C), 72.9, 71.2, 68.9, 55.2, 36.7, 36.3, 32.0, 23.9, 23.0, 14.8; HRMS (ESI) calcd for $C_{19}H_{28}O_4SNa$ [(M + Na)$^+$] 375.1601, found 375.1593.

(±)-**2b.** According to **GP1**, (±)-**2b** was prepared from (±)-**1** and *S*-phenyl 2-propenthioate:[55] IR (film) 3457, 2936, 2861, 1685, 1513, 1248, 1089, 1034, 820, 747 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.43−7.37 (m, 5H), 7.25−7.21 (m, 2H), 6.96 (ddd, *J* = 15.4, 6.9, 6.8 Hz, 1H), 6.88−6.84 (m, 2H), 6.17 (ddd, *J* = 15.4, 1.4, 1.3 Hz, 1H), 4.44 (s, 2H), 3.81−3.77 (m, 4H), 3.68 (m, 1H), 3.61 (m, 1H), 3.01 (br d, *J* = 2.4 Hz, 1H), 2.27−2.19 (m, 2H), 1.76−1.60 (m, 3H), 1.57−1.40 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.0, 159.3, 146.5, 134.6 (2C), 134.5, 129.9, 129.3 (2C), 129.1 (2C), 127.9, 127.6, 113.8 (2C), 73.0, 71.3, 68.9, 55.2, 36.7, 36.3, 32.2, 23.9; HRMS (ESI) calcd for $C_{23}H_{28}O_4SNa$ [(M + Na)$^+$] 423.1601, found 423.1603.

(±)-**2c.** According to **GP1**, (±)-**2c** was prepared from (±)-**1** and *S*-(4-methylphenyl) 2-propenthioate.[55] IR (film) 3464, 2935, 2861, 1685, 1513, 1248, 1091, 1034, 809 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.30−7.28 (m, 2H), 7.24−7.19 (m, 4H), 7.95 (ddd, *J* = 15.5, 6.9, 6.8 Hz, 1H), 6.87−6.85 (m, 2H), 6.16 (ddd, *J* = 15.5, 1.7, 1.4 Hz, 1H), 4.44 (s, 2H), 3.81−3.76 (m, 4H), 3.68 (m, 1H), 3.61 (m, 1H), 3.01 (br d, *J* = 3.2 Hz, 1H), 2.36 (s, 3H), 2.25−2.21 (m, 2H), 1.76−1.60 (m, 3H), 1.56−1.40 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.5, 159.3, 146.3, 139.5, 134.6 (2C), 129.94 (2C), 129.87, 129.3 (2C), 128.0, 124.1, 113.8 (2C), 73.0, 71.2, 68.9, 52.2, 36.7, 36.3, 32.2, 23.9, 21.3; HRMS (ESI) calcd for $C_{24}H_{30}O_4SNa$ [(M + Na)$^+$] 437.1757, found 437.1744.

(±)-**2d.** According to **GP1**, (±)-**2d** was prepared from (±)-**1** and *S*-(4-methoxyphenyl) 2-propenthioate:[55] IR (film) 3481, 2936, 2860, 1682, 1495, 1290, 1031, 826 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.33−7.30 (m, 2H), 7.24−7.21 (m, 2H), 6.94 (ddd, *J* = 15.5, 1.7, 1.4 Hz, 1H), 6.93−6.91 (m, 2H), 6.87−6.84 (m, 2H), 6.12 (ddd, *J* = 15.5, 1.7, 1.4 Hz, 1H), 4.44 (s, 2H), 3.81 (s, 3H), 3.80−3.76 (m, 4H), 3.68 (m, 1H), 3.60 (m, 1H), 3.01 (br d, *J* = 2.7 Hz, 1H), 2.25−2.20 (m, 2H), 1.76−1.60 (m, 3H), 1.55−1.40 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 189.0, 160.6, 159.3, 146.3, 136.2 (2C), 129.9, 129.3 (2C), 127.9, 118.2, 114.8 (2C), 113.8 (2C), 73.0, 71.3, 69.0, 55.3, 55.2, 36.7, 36.3, 32.2, 23.9; HRMS (ESI) calcd for $C_{24}H_{30}O_5SNa$ [(M + Na)$^+$] 453.1706, found 453.1710.

(±)-**2e.** According to **GP1**, (±)-**2e** was prepared from (±)-**1** and *S*-(4-nitrophenyl) 2-propenthioate:[55] IR (film) 3446, 2936, 2860, 1687, 1517, 1343, 1089, 852, 819 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.24−8.22 (m, 2H), 7.62−7.60 (m, 2H), 7.23−7.20 (m, 2H), 7.02 (ddd, *J* = 15.5, 6.9, 6.8 Hz, 1H), 6.87−6.84 (m, 2H), 6.18 (ddd, *J* = 15.5, 1.7, 1.4 Hz, 1H), 4.43 (s, 2H), 3.81−3.78 (m, 4H), 3.69 (ddd, *J* = 9.6, 5.5, 5.2 Hz, 1H), 3.61 (ddd, *J* = 9.6, 4.4, 4.1 Hz, 1H), 3.05 (br d, *J* = 2.8 Hz, 1H), 2.32−2.23 (m, 2H), 1.77−1.62 (m, 3H), 1.58−1.40 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 185.6, 159.3, 148.3, 148.0, 136.4, 134.8 (2C), 129.8, 129.3 (2C), 127.6, 123.8 (2C), 113.8 (2C), 73.0, 71.3, 69.0, 55.2, 36.7, 36.3, 32.3, 23.9; HRMS (ESI) calcd for $C_{23}H_{27}NO_6SNa$ [(M + Na)$^+$] 468.1451, found 468.1447.

(±)-**2f.** According to **GP1**, (±)-**2f** was prepared from (±)-**1** and *S*-(1-naphthyl) 2-propenthioate:[21a] IR (film) 3462, 2935, 2860, 1629, 1457, 1090, 850, 747 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.95 (s, 1H), 7.87−7.79 (m, 3H), 7.52−7.45 (m, 3H), 7.25−7.21 (m, 2H), 6.99 (ddd, *J* = 15.5, 6.9, 6.8 Hz, 1H), 6.88−6.85 (m, 2H), 6.21 (ddd, *J* = 15.5, 1.7, 1.4 Hz, 1H), 4.44 (s, 2H), 3.82−3.77 (m, 4H), 3.69 (m, 1H), 3.61 (m, 1H), 3.03 (br s, 1H), 2.28−2.23 (m, 2H), 1.77−1.62 (m, 3H), 1.59−1.41 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.2, 159.3, 146.7, 134.4, 133.5, 133.3, 131.1, 129.9, 129.3 (2C), 128.7, 128.0, 127.9, 127.7, 127.0, 126.5, 125.0, 113.8 (2C), 73.0, 71.3, 69.0,

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55.2, 36.7, 36.3, 32.2, 23.9; HRMS (ESI) calcd for $C_{27}H_{30}O_4SNa$ [(M + Na)$^+$] 473.1757, found 473.1767.

(±)-**14.** According to **GP1**, (±)-**14** was prepared from (±)-**4** and *S*-(4-methylphenyl) 2-propenthioate: IR (film) 3510, 2930, 2857, 1686, 1631, 1427, 1112, 1016, 808, 703 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.68−7.65 (m, 4H), 7.45−7.41 (m, 2H), 7.41−7.37 (m, 4H), 7.31−7.29 (m, 2H), 7.22−7.19 (m, 2H), 6.96 (ddd, *J* = 15.5, 6.9, 6.8 Hz, 1H), 6.18 (ddd, *J* = 15.5, 1.4, 1.4 Hz, 1H), 3.92−3.82 (m, 3H), 3.35 (br d, *J* = 2.4 Hz, 1H), 2.36 (s, 3H), 2.27−2.22 (m, 2H), 1.74−1.60 (m, 3H), 1.59−1.50 (m, 2H), 1.45 (m, 1H), 1.04 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.5, 146.3, 139.5, 135.5 (3C), 134.6 (2C), 132.9, 132.8, 129.95 (2C), 129.87 (2C), 129.85, 128.0, 127.8 (4C), 124.1, 71.6, 63.6, 38.3, 36.9, 32.2, 26.8 (3C), 23.9, 21.3, 19.0; HRMS (ESI) calcd for $C_{32}H_{40}O_3SSiNa$ [(M + Na)$^+$] 555.2360, found 555.2363.

(−)-**15.** According to **GP1**, (−)-**15** was prepared from (−)-**5** and *S*-(4-methylphenyl) 2-propenthioate: $[\alpha]^{28}_D$ −16.6 (*c* 1.00, $CHCl_3$); IR (film) 3519, 2942, 2865, 1687, 1464, 1112, 1015, 807, 702, 505 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.68−7.63 (m, 4H), 7.44−7.40 (m, 2H), 7.40−7.35 (m, 4H), 7.31−7.28 (m, 2H), 7.22−7.19 (m, 2H), 6.97 (ddd, *J* = 15.5, 7.6, 7.2 Hz, 1H), 6.20 (ddd, *J* = 15.5, 1.4, 1.4 Hz, 1H), 4.30 (dddd, *J* = 6.9, 6.5, 4.5, 3.8 Hz, 1H), 4.17 (m, 1H), 3.88−3.79 (m, 2H), 3.50 (br d, *J* = 2.1 Hz, 1H), 2.57 (dddd, *J* = 14.4, 7.2, 3.8, 1.4 Hz, 1H), 2.50 (dddd, *J* = 14.4, 7.6, 4.5, 1.4 Hz, 1H), 2.36 (s, 3H), 1.75−1.65 (m, 2H), 1.62 (m, 1H), 1.54 (ddd, *J* = 14.4, 6.5, 2.5 Hz, 1H), 1.12−1.05 (m, 21H), 1.04 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.3, 142.3, 139.6, 135.5 (4C), 134.6 (2C), 134.5, 133.2, 133.1, 130.03, 129.98 (2C), 129.8, 127.7 (4C), 124.0, 69.4, 67.3, 62.7, 43.7, 40.5, 39.4, 26.8 (3C), 21.3, 19.0, 18.2 (6C), 12.6 (3C); HRMS (ESI) calcd for $C_{41}H_{60}O_4SSi_2Na$ [(M + Na)$^+$] 727.3643, found 727.3649.

(−)-**16.** According to **GP1**, (−)-**16** was prepared from (−)-**6** and *S*-(4-methylphenyl) 2-propenthioate: $[\alpha]^{27}_D$ −1.4 (*c* 1.00, $CHCl_3$); IR (film) 3484, 2943, 2865, 1686, 1632, 1463, 1097, 1014, 807, 679 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.36−7.26 (m, 7H), 7.22−7.19 (m, 2H), 7.02 (ddd, *J* = 14.4, 7.9, 6.9 Hz, 1H), 6.21 (ddd, *J* = 14.4, 1.4, 1.4 Hz, 1H), 4.54 (s, 2H), 4.25 (m, 1H), 3.93 (m, 1H), 3.45 (dd, *J* = 9.6, 3.8 Hz, 1H), 3.33 (dd, *J* = 9.6, 7.6 Hz, 1H), 2.64 (br d, *J* = 2.4 Hz, 1H), 2.57 (dddd, *J* = 14.1, 12.7, 6.9, 1.4 Hz, 1H), 2.46 (dddd, *J* = 14.1, 7.9, 4.8, 1.4 Hz, 1H), 2.36 (s, 3H), 1.69 (ddd, *J* = 14.1, 9.6, 5.5 Hz, 1H), 1.59 (ddd, *J* = 14.1, 7.2, 2.8 Hz, 1H), 1.08−1.04 (m, 21H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.3, 142.5, 139.6, 137.9, 134.6 (2C), 130.1, 130.0 (2C), 128.5 (2C), 127.79, 127.76 (2C), 124.0, 74.7, 73.3, 69.3, 67.8, 39.8, 39.6, 21.3, 18.1 (6C), 12.6 (3C); HRMS (ESI) calcd for $C_{31}H_{46}O_4SSiNa$ [(M + Na)$^+$] 565.2778, found 565.2764.

(+)-**17.** According to **GP1**, (+)-**17** was prepared from (+)-**7** and *S*-(4-methylphenyl) 2-propenthioate: $[\alpha]^{29}_D$ +14.6 (*c* 1.00, $CHCl_3$); IR (film) 3511, 2929, 2857, 1685, 1427, 1255, 1110, 1015, 776, 703 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.67−7.61 (m, 4H), 7.42−7.32 (m, 6H), 7.30−7.26 (m, 2H), 7.22−7.18 (m, 2H), 6.84 (ddd, *J* = 15.5, 7.9, 7.6 Hz, 1H), 6.17 (d, *J* = 15.5 Hz, 1H), 3.96 (m, 1H), 3.88 (ddd, *J* = 7.2, 5.8, 3.4 Hz, 1H), 3.72−3.62 (m, 2H), 3.23 (br s, 1H), 2.58−2.46 (m, 2H), 2.36 (s, 3H), 1.65 (m, 1H), 1.60−1.47 (m, 3H), 1.43 (m, 1H), 1.02 (s, 9H), 0.96 (d, *J* = 7.2 Hz, 3H), 0.89 (s, 9H), 0.090 (s, 3H), 0.088 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.1, 141.8, 139.7, 135.5 (4C), 134.5 (2C), 133.89, 133.86, 130.0 (2C), 129.9, 129.5 (2C), 127.6 (4C), 123.8, 76.6, 70.2, 63.9, 40.1, 38.1, 31.3, 29.2, 26.8 (3C), 25.8 (3C), 21.3, 19.2, 17.9, 10.7, −4.4, −4.7; HRMS (ESI) calcd for $C_{40}H_{58}O_4SSi_2Na$ [(M + Na)$^+$] 713.3487, found 713.3490.

(+)-**18.** According to **GP1**, (+)-**18** was prepared from (+)-**8** and *S*-(4-methylphenyl) 2-propenthioate: $[\alpha]^{22}_D$ +35.2 (*c* 1.00, $CHCl_3$); IR (film) 2848, 1703, 999, 960, 807 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.31−7.28 (m, 2H), 7.21−7.19 (m, 2H), 6.99 (ddd, *J* = 15.5, 6.8, 6.8 Hz, 1H), 6.19 (ddd, *J* = 15.5, 1.4, 1.4 Hz, 1H), 3.88 (dddd, *J* = 11.3, 4.1, 2.1, 1.7 Hz, 1H), 3.33−3.25 (m, 2H), 2.98 (ddd, *J* = 9.3, 8.9, 2.4 Hz, 1H), 2.44 (m, 1H), 2.36 (s, 3H), 2.29 (m, 1H), 2.09 (m, 1H), 2.03 (m, 1H), 1.70−1.64 (m, 2H), 1.57 (m, 1H), 1.42−1.35 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.7, 146.4, 139.5, 134.6 (2C), 129.9 (2C), 127.9, 124.0, 81.3, 70.3, 67.5, 33.1, 30.3, 28.1, 25.6, 21.3; HRMS (ESI) calcd for $C_{17}H_{22}O_3SNa$ [(M + Na)$^+$] 329.1182, found 329.1173.

(+)-**19.** According to **GP1**, (+)-**19** was prepared from (+)-**9** and *S*-(4-methylphenyl) 2-propenthioate: $[\alpha]^{25}_D$ +40.5 (*c* 1.00, $CHCl_3$); IR (film) 3352, 2938, 2855, 1682, 1632, 1093, 1042, 808 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.31−7.28 (m, 2H), 7.22−7.18 (m, 2H), 7.00 (ddd, *J* = 15.5, 7.2, 7.2 Hz, 1H), 6.25 (ddd, *J* = 15.5, 1.4, 1.4 Hz, 1H), 4.04 (m, 1H), 3.92 (m, 1H), 3.68 (m, 1H), 3.33 (m, 1H), 2.96 (dd, *J* = 8.9, 2.0 Hz, 1H), 2.55 (dddd, *J* = 14.4, 8.2, 7.2, 1.4 Hz, 1H), 2.48 (dddd, *J* = 14.4, 7.2, 5.8, 1.4 Hz, 1H), 2.36 (s, 3H), 2.17 (br s, 1H), 2.12 (m, 1H), 1.70−1.59 (m, 3H), 1.42 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.5, 142.9, 139.6, 134.6 (2C), 130.0 (2C), 129.8, 124.0, 82.5, 68.9, 67.8, 66.2, 36.9, 32.7, 25.3, 21.3; HRMS (ESI) calcd for $C_{17}H_{22}O_4SNa$ [(M + Na)$^+$] 345.1131, found 345.1144.

(−)-**20.** According to **GP1**, (−)-**20** was prepared from (+)-**10** and *S*-(4-methylphenyl) 2-propenthioate: $[\alpha]^{26}_D$ −6.9 (*c* 1.00, $CHCl_3$); IR (film) 3364, 2938, 2853, 1673, 1632, 1437, 1096, 1029, 967, 808 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.32−7.28 (m, 2H), 7.23−7.19 (m, 2H), 7.01 (ddd, *J* = 15.5, 8.2, 6.8 Hz, 1H), 6.27 (ddd, *J* = 15.5, 1.4, 1.4 Hz, 1H), 3.94−3.87 (m, 2H), 3.59 (dddd, *J* = 14.1, 8.6, 4.5, 4.5 Hz, 1H), 3.30 (m, 1H), 2.96 (dd, *J* = 8.6, 7.9 Hz, 1H), 2.88 (m, 1H), 2.74 (m, 1H), 2.67 (dddd, *J* = 14.4, 6.8, 3.4, 1.7 Hz, 1H), 2.42 (ddd, *J* = 15.1, 8.3, 7.9 Hz, 1H), 2.36 (s, 3H), 2.10 (m, 1H), 1.68−1.63 (m, 2H), 1.44 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 188.5, 142.5, 139.7, 134.6 (2C), 130.3, 130.0 (2C), 123.9, 81.9, 73.7, 70.9, 67.7, 36.5, 32.6, 25.2, 21.3; HRMS (ESI) calcd for $C_{17}H_{22}O_4SNa$ [(M + Na)$^+$] 345.1131, found 345.1139.

2,6-*cis*-Substituted Tetrahydropyrans 3a−f and 21−27. *General Procedure for Intramolecular Oxa-Conjugate Cyclization of α,β-Unsaturated Thioesters (**GP2**).* To a solution of (±)-**14** (36.3 mg, 0.0681 mmol) in DCE (1.0 mL) was added CSA (3.2 mg, 0.014 mmol), and the resultant solution was stirred at 70 °C for 30 h. After complete consumption of (±)-**14**, the reaction mixture was cooled to room temperature. The reaction was quenched with Et_3N, and the resultant mixture was concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (2 to 20% EtOAc/hexanes) gave 2,6-*cis*-substituted tetrahydropyran (±)-**21** (32.1 mg, 88%) as a colorless oil.

(±)-**3a.** Synthesized from (±)-**2a** according to **GP2** except that the reaction was performed in CH_2Cl_2 at room temperature: IR (film) 2932, 2858, 1685, 1513, 1247, 1089, 1037, 820 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.25−7.22 (m, 2H), 6.87−6.84 (m, 2H), 4.38 (s, 2H), 3.79−3.74 (m, 4H), 3.55−3.48 (m, 2H), 3.45 (m, 1H), 2.89−2.80 (m, 2H), 2.74 (dd, *J* = 14.5, 7.6 Hz, 1H), 2.55 (dd, *J* = 14.5, 5.2 Hz, 1H), 1.79 (m, 1H), 1.74−1.64 (m, 2H), 1.59 (m, 1H), 1.56−1.46 (m, 2H), 1.22, (t, *J* = 7.6 Hz, 3H), 1.23−1.14 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 197.4, 159.1, 130.8, 129.2 (2C), 113.7 (2C), 74.9, 74.5, 72.7, 66.6, 55.2, 50.8, 36.5, 31.3, 31.2, 23.4, 23.3, 14.8; HRMS (ESI) calcd for $C_{19}H_{28}O_4SNa$ [(M + Na)$^+$] 375.1601, found 375.1605.

(±)-**3b.** Synthesized from (±)-**2b** according to **GP2** except that the reaction was performed in CH_2Cl_2 at room temperature: IR (film) 2934, 2857, 1705, 1513, 1247, 1089, 820, 745 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.38 (m, 5H), 7.23−7.20 (m, 2H), 6.85−6.82 (m, 2H), 4.39 (s, 2H), 3.80 (m, 1H), 3.76 (s, 3H), 3.59−3.52 (m, 2H), 3.48 (m, 1H), 2.84 (dd, *J* = 14.5, 7.8 Hz, 1H), 2.65 (dd, *J* = 14.5, 5.2 Hz, 1H), 1.81 (m, 1H), 1.78−1.67 (m, 2H), 1.63 (m, 1H), 1.57−1.48 (m, 2H), 1.28−1.16 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 192.3, 159.0, 134.4 (2C), 130.7, 129.3, 129.2 (2C), 129.1 (2C), 127.9, 113.7 (2C), 75.0, 74.5, 72.7, 66.6, 55.2, 50.3, 36.6, 31.3, 31.2, 23.4; HRMS (ESI) calcd for $C_{23}H_{28}O_4SNa$ [(M + Na)$^+$] 423.1601, found 423.1598.

(±)-**3c.** Synthesized from (±)-**2c** according to **GP2** except that the reaction was performed in CH_2Cl_2 at room temperature: IR (film) 2932, 2857, 1704, 1513, 1089, 1036, 808 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.27−7.17 (m, 6H), 6.86−6.82 (m, 2H), 4.39 (s, 2H), 3.82−3.76 (m, 4H), 3.59−3.51 (m, 2H), 3.47 (m, 1H), 2.83 (dd, *J* = 14.8, 7.9 Hz, 1H), 2.63 (dd, *J* = 14.8, 5.2 Hz, 1H), 2.35 (s, 3H), 1.81 (m, 1H), 1.78−1.67 (m, 2H), 1.63 (m, 1H), 1.56−1.47 (m, 2H), 1.27−1.16 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.8, 159.0, 139.6, 134.5 (2C), 130.7, 129.9 (2C), 129.2 (2C), 124.4, 113.7 (2C),

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75.0, 74.5, 72.7, 66.6, 55.2, 50.2, 36.6, 31.3, 31.2, 23.3, 21.3; HRMS (ESI) calcd for $C_{24}H_{30}O_4SNa$ [(M + Na)$^+$] 437.1757, found 437.1757.

(±)-**3d.** Synthesized from (±)-**2d** according to **GP2** except that the reaction was performed in CH_2Cl_2 at room temperature: IR (film) 2935, 2857, 1703, 1513, 1249, 1089, 826 cm^{-1}; ^{1}H NMR (600 MHz, C_6D_6) δ 7.37−7.34 (m, 2H), 7.27−7.24 (m, 2H), 6.82−6.79 (m, 2H), 6.69−6.67 (m, 2H), 4.39 (s, 2H), 3.78 (m, 1H), 3.66 (m, 1H), 3.57 (m, 1H), 3.43 (m, 1H), 3.29 (s, 3H), 3.16 (s, 3H), 2.79 (dd, J = 14.8, 7.9 Hz, 1H), 2.43 (dd, J = 14.8, 4.8 Hz, 1H), 1.83 (m, 1H), 1.74 (m, 1H), 1.47 (m, 1H), 1.30−1.23 (m, 2H), 1.18 (m, 1H), 1.07−0.95 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 196.3, 160.5, 159.0, 136.0 (2C), 130.7, 129.2 (2C), 118.6, 114.8 (2C), 113.7 (2C), 75.0, 74.5, 72.6, 66.6, 55.3, 55.2, 50.1, 36.6, 31.3, 31.2, 23.4; HRMS (ESI) calcd for $C_{24}H_{30}O_5SNa$ [(M + Na)$^+$] 453.1706, found 453.1708.

(±)-**3e.** Synthesized from (±)-**2e** according to **GP2** except that the reaction was performed in CH_2Cl_2 at room temperature: IR (film) 2933, 2856, 1709, 1517, 1343, 1088, 852, 743 cm^{-1}; ^{1}H NMR (600 MHz, C_6D_6) δ 7.71−7.68 (m, 2H), 7.23−7.20 (m, 2H), 7.08−7.05 (m, 2H), 6.81−6.78 (m, 2H), 4.36 (s, 2H), 3.67 (dddd, J = 12.7, 8.6, 4.1, 2.0 Hz, 1H), 3.61 (m, 1H), 3.51 (m, 1H), 3.42 (dddd, J = 12.7, 8.3, 4.1, 1.7 Hz, 1H), 3.29 (s, 3H), 2.63 (dd, J = 14.8, 8.6 Hz, 1H), 2.30 (dd, J = 14.8, 4.1 Hz, 1H), 1.82 (m, 1H), 1.72 (m, 1H), 1.48 (m, 1H), 1.26 (m, 1H), 1.12−1.20 (m, 2H), 1.02 (m, 1H), 0.95 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 193.2, 159.1, 148.0, 136.5, 134.6 (2C), 130.6, 129.0 (2C), 123.9 (2C), 113.7 (2C), 75.0, 74.4, 72.6, 66.5, 55.2, 50.7, 36.5, 31.2 (2C), 23.3; HRMS (ESI) calcd for $C_{23}H_{27}NO_6SNa$ [(M + Na)$^+$] 468.1451, found 468.1449.

(±)-**3f.** Synthesized from (±)-**2f** according to **GP2** except that the reaction was performed in CH_2Cl_2 at room temperature: IR (film) 2933, 2856, 1703, 1512, 1247, 1088, 814, 746 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.91 (s, 1H), 7.84−7.82 (m, 2H), 7.78 (d, J = 7.9 Hz, 1H), 7.52−7.46 (m, 2H), 7.42 (dd, J = 8.6, 1.7 Hz, 1H), 7.21 (m, 2H), 6.82 (m, 2H), 4.41 (d, J = 11.3 Hz, 1H), 4.38 (d, J = 11.3 Hz, 1H), 3.84 (dddd, J = 13.0, 7.9, 5.2, 2.0 Hz, 1H), 3.74 (s, 3H), 3.62−3.54 (m, 2H), 3.50 (dddd, J = 12.7, 8.2, 4.1, 1.7 Hz, 1H), 2.89 (dd, J = 14.4, 7.9 Hz, 1H), 2.69 (dd, J = 14.4, 5.2 Hz, 1H), 1.83 (m, 1H), 1.79−1.68 (m, 2H), 1.66 (m, 1H), 1.58−1.49 (m, 2H), 1.30−1.18 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.5, 159.0, 134.1, 133.5, 133.3, 130.9, 130.7, 129.2 (2C), 128.7, 127.9, 127.7, 127.1, 126.5, 125.3, 113.7 (2C), 75.0, 74.5, 72.7, 66.6, 55.2, 50.4, 36.6, 31.3, 31.2, 23.3; HRMS (ESI) calcd for $C_{27}H_{30}O_4SNa$ [(M + Na)$^+$] 473.1757, found 473.1751.

(±)-**21:** IR (film) 2931, 2856, 1705, 1427, 1110, 996, 806, 703 cm^{-1}; ^{1}H NMR (600 MHz, C_6D_6) δ 7.82 (m, 4H), 7.32−7.21 (m, 8H), 6.88−6.86 (m, 2H), 3.95 (m, 1H), 3.88 (ddd, J = 11.0, 6.2, 5.8 Hz, 1H), 3.74 (apparent ddd, J = 11.3, 7.3, 5.9 Hz, 1H), 3.41 (dddd, J = 12.4, 9.2, 3.7, 1.7 Hz, 1H), 2.77 (dd, J = 14.5, 7.3 Hz, 1H), 2.43 (dd, J = 14.5, 5.9 Hz, 1H), 1.98 (s, 3H), 1.81 (m, 1H), 1.69 (m, 1H), 1.46 (m, 1H), 1.33 (m, 1H), 1.25−1.12 (m, 11H), 1.05−0.95 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.8, 139.5, 135.5 (4C), 134.4 (2C), 134.1, 134.0, 129.9 (2C), 129.5 (2C), 127.6 (4C), 124.3, 74.8, 74.3, 60.4, 50.2, 39.4, 31.3, 31.2, 26.9 (3C), 23.4, 21.3, 19.2; HRMS (ESI) calcd for $C_{32}H_{40}O_3SSiNa$ [(M + Na)$^+$] 555.2360, found 555.2375.

(−)-**22.:** According to **GP2**, (−)-**22** was synthesized from (−)-**15** (reaction time: 7.5 h): $[\alpha]^{29}_D$ −3.2 (c 1.00, $CHCl_3$); IR (film) 2942, 2864, 1463, 1112, 806, 702 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.64−7.61 (m, 4H), 7.39−7.36 (m, 2H), 7.35−7.31 (m, 4H), 7.20−7.19 (m, 2H), 7.16−7.13 (m, 2H), 3.84 (dddd, J = 11.3, 11.3, 4.8, 4.8 Hz, 1H), 3.80−3.75 (m, 2H), 3.72 (dddd, J = 12.1, 7.6, 5.5, 2.4 Hz, 1H), 3.49 (dddd, J = 11.3, 8.3, 4.1, 2.4 Hz, 1H), 2.85 (dd, J = 14.8, 7.6 Hz, 1H), 2.64 (dd, J = 14.8, 5.5 Hz, 1H), 2.35 (s, 3H), 1.96 (ddd, J = 12.7, 4.8, 2.4 Hz, 1H), 1.88 (ddd, J = 12.7, 4.8, 2.4 Hz, 1H), 1.80 (m, 1H), 1.69 (m, 1H), 1.26 (ddd, J = 12.7, 12.1, 11.3 Hz, 1H), 1.24 (ddd, J = 12.7, 11.3, 11.3 Hz, 1H), 1.04−1.02 (m, 21H), 1.01 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.6, 139.6, 135.5 (4C), 134.4 (2C), 133.98, 133.96, 123.0 (2C), 129.52, 129.50, 127.6 (4C), 124.2, 72.6, 72.1, 68.4, 60.5, 49.7, 41.7, 41.4, 38.9, 26.9 (3C), 21.3, 19.2, 18.1 (6C), 12.3 (3C); HRMS (ESI) calcd for $C_{41}H_{60}O_4SSi_2Na$ [(M + Na)$^+$] 727.3643, found 727.3665.

(+)-**23.** According to **GP2**, (+)-**23** was synthesized from (−)-**16** (reaction time: 6 h): $[\alpha]^{27}_D$ +14.7 (c 1.00, $CHCl_3$); IR (film) 2942, 2865, 1707, 1463, 1106, 1068, 1044, 687 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.34−7.29 (m, 4H), 7.27−7.22 (m, 3H), 7.18−7.15 (m, 2H), 4.61 (d, J = 12.4 Hz, 1H), 4.57 (d, J = 12.4 Hz, 1H), 4.36 (dddd, J = 12.0, 7.2, 6.2, 2.1 Hz, 1H), 4.32 (dddd, J = 3.2, 3.1, 2.8, 2.4 Hz, 1H), 4.13 (dddd, J = 11.7, 5.2, 4.8, 2.1 Hz, 1H), 3.48−3.45 (m, 2H), 2.93 (dd, J = 14.4, 7.2 Hz, 1H), 2.66 (dd, J = 14.4, 6.2 Hz, 1H), 2.34 (s, 3H), 1.74 (dddd, J = 13.4, 3.2, 2.1, 1.4 Hz, 1H), 1.60 (dddd, J = 13.4, 3.1, 2.1, 1.4 Hz, 1H), 1.51 (ddd, J = 13.4, 11.7, 2.8 Hz, 1H), 1.48 (ddd, J = 13.4, 12.0, 2.4, Hz, 1H), 1.04 (s, 18H), 1.03 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.4, 139.5, 138.6, 134.4 (2C), 129.9 (2C), 128.3 (2C), 127.6 (2C), 127.4, 124.4, 73.34, 73.27, 71.7, 69.0, 64.7, 50.0, 38.9, 35.6, 21.3, 18.1 (6C), 12.2 (3C); HRMS (ESI) calcd for $C_{31}H_{46}O_4SSiNa$ [(M + Na)$^+$] 565.2778, found 565.2761.

(−)-**24.** According to **GP2**, (−)-**24** was synthesized from (+)-**17** (reaction time: 4.5 h): $[\alpha]^{30}_D$ −1.5 (c 1.00, $CHCl_3$); IR (film) 2928, 2856, 1706, 1389, 1252, 1110, 741, 702 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.67−7.64 (m, 4H), 7.42−7.38 (m, 2H), 7.37−7.34 (m, 4H), 7.26−7.23 (m, 2H), 7.18−7.15 (m, 2H), 3.79 (ddd, J = 11.0, 9.7, 4.8 Hz, 1H), 3.73 (dddd, J = 12.7, 7.6, 5.2, 2.4 Hz, 1H), 3.68 (ddd, J = 10.3, 6.2, 5.9 Hz, 1H), 3.63 (ddd, J = 10.3, 6.2, 5.9 Hz, 1H), 3.25 (m, 1H), 2.87 (dd, J = 14.8, 7.6 Hz, 1H), 2.62 (dd, J = 14.8, 5.2 Hz, 1H), 2.34 (s, 3H), 1.72−1.65 (m, 2H), 1.63−1.52 (m, 3H), 1.45−1.39 (m, 2H), 1.04 (s, 9H), 0.87 (s, 9H), 0.83 (d, J = 6.8 Hz, 3H), 0.04 (s, 3H), 0.03 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.9, 139.7, 135.7 (4C), 134.6 (2C), 134.1 (2C), 130.1 (2C), 129.6 (2C), 127.7 (4C), 124.4, 78.8, 72.8, 71.4, 64.0, 49.7, 39.0, 35.7, 29.19, 29.15, 27.0 (3C), 25.9 (3C), 21.4, 19.3, 18.2, 5.2, −4.5, −4.6; HRMS (ESI) calcd for $C_{40}H_{58}O_4SSi_2Na$ [(M + Na)$^+$] 713.3487, found 713.3499.

(+)-**25.** According to **GP2**, (+)-**25** was synthesized from (+)-**18** (reaction time: 23 h): $[\alpha]^{22}_D$ +23.7 (c 1.00, $CHCl_3$); IR (film) 3444, 2936, 2851, 1683, 1630, 1439, 1094, 1043, 807 cm^{-1}; ^{1}H NMR (600 MHz, C_6D_6) δ 7.34−7.32 (m, 2H), 6.88−6.85 (m, 2H), 3.80 (dddd, J = 12.7, 7.6, 5.2, 2.4 Hz, 1H), 3.66 (apparent dd, J = 11.3, 4.8 Hz, 1H), 3.05 (ddd, J = 12.0, 11.3, 2.4, Hz, 1H), 2.90 (ddd, J = 10.6, 8.9, 4.5 Hz, 1H), 2.78 (ddd, J = 10.6, 8.9, 4.8 Hz, 1H), 2.77 (dd, J = 15.1, 7.6 Hz, 1H), 2.37 (dd, J = 15.1, 5.2 Hz, 1H), 1.96 (s, 3H), 1.88−1.82 (m, 2H), 1.45−1.27 (m, 4H), 1.19−1.12 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.5, 139.7, 134.4 (2C), 130.0 (2C), 124.1, 78.3, 78.0, 74.0, 68.0, 49.4, 30.9, 29.5, 29.4, 25.7, 21.3; HRMS (ESI) calcd for $C_{17}H_{22}O_3SNa$ [(M + Na)$^+$] 329.1182, found 329.1172.

(+)-**26.** According to **GP2**, (+)-**26** was synthesized from (+)-**19** (reaction time: 10.5 h): $[\alpha]^{29}_D$ +20.2 (c 1.00, $CHCl_3$); IR (film) 3450, 2943, 2865, 1703, 1100, 959, 808, 767 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.27−7.25 (m, 2H), 7.20−7.17 (m, 2H), 4.31 (dddd, J = 13.4, 7.6, 5.2, 2.4 Hz, 1H), 4.08 (ddd, J = 3.1, 2.8, 2.8 Hz, 1H), 3.92 (m, 1H), 3.60 (ddd, J = 11.3, 9.3, 2.8 Hz, 1H), 3.44 (m, 1H), 3.00 (dd, J = 9.3, 2.8 Hz, 1H), 2.84 (dd, J = 15.1, 7.6 Hz, 1H), 2.64 (dd, J = 15.1, 5.2 Hz, 1H), 2.35 (s, 3H), 2.29 (br s, 1H), 2.04 (m, 1H), 1.96 (ddd, J = 14.1, 3.1, 2.4 Hz, 1H), 1.72−1.58 (m, 3H), 1.42 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.1, 139.6, 134.4 (2C), 130.0 (2C), 124.2, 79.7, 70.8, 68.8, 68.2, 65.7, 49.1, 37.2, 29.3, 25.5, 21.3; HRMS (ESI) calcd for $C_{17}H_{22}O_4SNa$ [(M + Na)$^+$] 345.1131, found 345.1139.

(+)-**27.** According to **GP2**, (+)-**27** was synthesized from (−)-**20** (reaction time: 10 h): $[\alpha]^{27}_D$ +31.5 (c 1.00, $CHCl_3$); IR (film) 3446, 2942, 2920, 1700, 1100, 963, 808, 756 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.27−7.25 (m, 2H), 7.21−7.18 (m, 2H), 3.96 (dddd, J = 12.7, 7.2, 5.5, 1.7 Hz, 1H), 3.92 (m, 1H), 3.70 (ddd, J = 11.3, 8.9, 5.2 Hz, 1H), 3.37 (m, 1H), 3.04 (ddd, J = 11.3, 8.9, 4.2 Hz, 1H), 2.93 (dd, J = 15.1, 7.2 Hz, 1H), 2.83 (dd, J = 8.9, 8.9 Hz, 1H), 2.70 (dd, J = 15.1, 5.5 Hz, 1H), 2.57 (br s, 1H), 2.35 (s, 3H), 2.09 (ddd, J = 12.7, 5.2, 1.7 Hz, 1H), 2.03 (m, 1H), 1.70−1.65 (m, 2H), 1.50−1.42 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 195.2, 139.8, 134.4 (2C), 130.0 (2C), 123.4, 83.7, 75.0, 72.0, 70.1, 67.9, 49.0, 38.4, 29.0, 25.4, 21.3; HRMS (ESI) calcd for $C_{17}H_{22}O_4SNa$ [(M + Na)$^+$] 345.1131, found 345.1140.

α,β-Unsaturated Amide/Imide Derivatives 28a−g and 30−42. (±)-**28a.** According to **GP1**, (±)-**28a** was prepared from (±)-**4** and 1-(2-propenoyl)-pyrrolidine:[56] IR (film) 3420, 2951, 2873, 1651, 1609, 1437, 1375, 1111, 981 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.67−7.64 (m, 4H), 7.44−7.34 (m, 5H), 6.85 (ddd, J = 15.0, 7.2, 6.6 Hz, 1H), 6.08 (d, J = 15.0 Hz, 1H), 3.90−3.80 (m, 3H), 3.52−3.46

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(m, 4H), 3.35 (br s, 1H), 2.23−2.19 (m, 2H), 1.97−1.90 (m, 2H), 1.87−1.82 (m, 2H), 1.72−1.42 (m, 8H), 1.03 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 164.8, 145.4, 135.5 (4C), 132.9, 129.8 (2C), 128.3, 121.8, 71.8, 63.7, 46.5, 45.8, 38.2, 37.0, 32.3, 26.8 (9C), 24.3, 19.0; HRMS (ESI) calcd for $C_{29}H_{42}NO_3Si$ [(M + H)$^+$] 480.2928, found 480.2938.

(±)-28b. According to **GP1**, (±)-**28b** was prepared from (±)-**4** and 1-(3-propenoyl)-2-pyrrolidinone:[57] IR (film) 3648, 2931, 1735, 1683, 1361, 1111, 704 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.67−7.64 (m, 4H), 7.44−7.34 (m, 6H), 7.23 (d, J = 13.8 Hz, 1H), 7.15 (ddd, J = 15.6, 7.2, 7.2 Hz, 1H), 3.90−3.80 (m, 5H), 3.32 (s, 1H), 2.58 (dd, J = 8.4, 7.8 Hz, 2H), 2.30−2.25 (m, 2H), 2.04−1.98 (m, 2H), 1.72−1.42 (m, 6H), 1.03 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.5, 166.2, 150.3 (2C), 135.5 (4C), 132.9, 132.8, 129.8 (2C), 127.7 (4C), 71.5, 63.5, 45.7, 38.3, 36.9, 33.9, 32.5, 26.8 (3C), 24.1, 19.0, 17.1; HRMS (ESI) calcd for $C_{29}H_{40}NO_4Si$ [(M + H)$^+$] 494.2721, found 494.2709.

(±)-28c. According to **GP1**, (±)-**28c** was prepared from (±)-**4** and 3-(2-propenoyl)-2-oxazolidinone:[58] IR (film) 3473, 2930, 1777, 1686, 1386, 1360, 1111, 823, 704 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.67−7.64 (m, 4H), 7.44−7.36 (m, 6H), 7.22 (d, J = 16.8 Hz, 1H), 7.15 (dt, J = 16.8, 6.9 Hz, 1H), 4.39 (dd, J = 8.3, 7.9 Hz, 2H), 4.04 (dd, J = 8.3, 7.9 Hz, 2H), 3.92−3.80 (m, 3H), 3.30 (m, 1H), 2.29 (dt, J = 8.6, 6.9 Hz, 2H), 1.73−1.59 (m, 3H), 1.58−1.41 (m, 3H), 1.03 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 165.2, 153.5, 151.4, 135.5 (4C), 132.9, 132.8, 129.8 (2C), 127.8 (4C), 120.1, 71.5, 63.6, 62.0, 42.7, 38.3, 36.9, 32.6, 26.8 (3C), 24.0, 19.0; HRMS (ESI) calcd for $C_{28}H_{37}NNaO_5Si$ [(M + Na)$^+$] 518.2333, found 518.2338.

(±)-28d. According to **GP1**, (±)-**28d** was prepared from (±)-**4** and 3-(2-propenoyl)-2-benzoxazolidinone:[58] IR (film) 3402, 2939, 2907, 1860, 1816, 1478, 1111, 702, 503 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.08 (m, 1H), 7.69−7.64 (m, 4H), 7.45−7.32 (m, 8H), 7.25−7.18 (m, 3H), 3.94−3.81 (m, 3H), 3.34 (s, 1H), 2.41−2.34 (m, 2H), 1.77−1.45 (m, 6H), 1.04 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 164.2, 154.0, 151.3 (2C), 142.3, 135.5 (2C), 132.9, 132.8, 129.8 (2C), 128.1, 127.8 (2C), 125.1 (2C), 124.7 (2C), 120.6 (2C), 116.1, 109.7, 71.5, 63.6, 38.3, 36.9, 32.9, 26.8 (3C), 24.0, 19.0; HRMS (ESI) calcd for $C_{32}H_{37}NNaO_5Si$ [(M + Na)$^+$] 566.2333, found 566.2354.

(±)-28e. According to **GP1**, (±)-**28e** was prepared from (±)-**4** and 1-(2-propenoyl)indole:[58] IR (film) 3502, 2931, 1685, 1636, 1451, 1111, 703 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.48 (d, J = 7.8 Hz, 1H), 7.68−7.64 (m, 4H), 7.55 (d, J = 7.8 Hz, 1H), 7.53 (d, J = 3.6 Hz, 1H), 7.45−7.32 (m, 8H), 7.27 (m, 1H), 6.68−6.62 (m, 2H), 3.96−3.82 (m, 3H), 3.45 (d, J = 1.8 Hz, 1H), 2.42−2.36 (m, 2H), 1.80−1.68 (m, 2H), 1.66−1.46 (m, 4H), 1.04 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 164.2, 151.2 (2C), 135.8, 135.5 (4C), 132.9, 132.8, 130.5, 129.9, 129.8, 127.8 (4C), 124.9, 124.7, 123.6, 120.9, 120.8, 116.8, 71.6, 63.6, 38.3, 36.9, 32.7, 26.8 (3C), 24.0, 19.0; HRMS (ESI) calcd for $C_{33}H_{39}NNaO_3Si$ [(M + Na)$^+$] 548.2591, found 548.2592.

(±)-28f. According to **GP1**, (±)-**28f** was prepared from (±)-**4** and 1-(2-propenoyl)indoline:[58] IR (film) 3648, 2921, 1653, 1541, 1112, 669 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.27 (m, 1H), 7.67−7.64 (m, 4H), 7.44−7.37 (m, 7H), 7.20−7.13 (m, 2H), 6.99 (dd, J = 7.8, 7.2 Hz, 1H), 6.22 (d, J = 14.4 Hz, 1H), 4.13 (dd, J = 9.0, 8.4 Hz, 2H), 3.92−3.81 (m, 3H), 3.40 (br s, 1H), 3.22−3.14 (m, 2H), 2.32−2.24 (m, 2H), 1.74−1.44 (m, 6H), 1.03 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 164.4, 147.4, 143.1, 135.5 (4C), 132.9, 132.8, 131.4, 129.9, 129.8, 127.8 (4C), 127.5, 124.4, 123.6, 122.1, 117.4, 71.7, 63.7, 48.0, 38.3, 37.0, 32.5, 28.0, 26.8 (3C), 24.3, 19.0; HRMS (ESI) calcd for $C_{33}H_{42}NO_3Si$ [(M + H)$^+$] 528.2928, found 528.2914.

(±)-28g. According to **GP1**, (±)-**28g** was prepared from (±)-**4** and 1-(2-propenoyl)-2,5-dimethylpyrrole:[28b] IR (film) 3749, 2929, 1696, 1636, 1427, 1366, 1253 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.67−7.64 (m, 4H), 7.45−7.34 (m, 6H), 7.03 (m, 1H), 6.34 (d, J = 15.5 Hz, 1H), 5.82−5.80 (m, 2H), 3.92−3.81 (m, 3H), 3.38 (br d, J = 2.4 Hz, 1H), 2.33−2.29 (m, 6H), 1.74−1.66 (m, 2H), 1.63−1.43 (m, 6H), 1.04 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.4, 150.9, 151.4, 135.5 (4C), 132.9, 132.8, 129.9 (2C), 129.8, 127.8 (4C), 125.5, 120.1, 110.6, 71.6, 63.7, 38.3, 37.0, 32.6, 26.8 (3C), 23.9, 19.0, 15.5 (2C); HRMS (ESI) calcd for $C_{31}H_{41}NO_3SiNa$ [(M + Na)$^+$] 526.2748, found 526.2730.

(±)-30. According to **GP1**, (±)-**30** was prepared from (±)-**1** and 3-(2-propenoyl)-2-oxazolidinone: IR (film) 2927, 1793, 1684, 1542, 1508, 1362 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.23−7.18 (m, 3H), 7.13 (m, 1H), 6.85 (d, J = 8.6 Hz, 2H), 4.42 (s, 2H), 4.38 (dd, J = 8.6, 7.9 Hz, 2H), 4.03 (dd, J = 8.6, 7.9 Hz, 2H), 3.81−3.73 (m, 4H), 3.66 (m, 1H), 3.59 (m, 1H), 2.98 (s, 1H), 2.32−2.23 (m, 2H), 1.75−1.40 (m, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 165.3, 159.3, 153.5, 151.4, 129.9, 129.3, 120.2 (2C), 113.8 (2C), 73.0, 71.3, 69.0, 62.0, 55.3, 42.7, 36.8, 36.3, 32.6, 24.1; HRMS (ESI) calcd for $C_{20}H_{27}NO_6Na$ [(M + Na)$^+$] 400.1731, found 400.1735.

(−)-31. According to **GP1**, (−)-**31** was prepared from (−)-**5** and 3-(2-propenoyl)-2-oxazolidinone: $[\alpha]^{22}_D$ −15.7 (c 1.00, $CHCl_3$); IR (film) 3566, 2942, 1781, 1684, 1387, 1223, 1111, 1038, 704 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.66−7.63 (m, 4H), 7.43−7.35 (m, 6H), 7.26 (d, J = 15.5 Hz, 1H), 7.15 (ddd, J = 15.5, 7.3, 7.3 Hz, 1H), 4.39 (dd, J = 8.2, 7.9 Hz, 2H), 4.29 (dddd, J = 7.2, 7.2, 4.4, 4.4 Hz, 1H), 4.15 (m, 1H), 4.03 (dd, J = 8.2, 7.9 Hz, 2H), 3.85−3.77 (m, 2H), 3.44 (d, J = 2.4 Hz, 1H), 2.64−2.54 (m, 2H), 1.74−1.51 (m, 4H), 1.11−1.01 (m, 30H) ;^{13}C NMR (150 MHz, $CDCl_3$) δ 164.8, 153.4, 147.1, 135.5 (4C), 133.3, 133.2, 129.7 (2C), 127.7 (4C), 122.2, 69.4, 67.3, 62.7, 62.0, 43.7, 42.6, 40.7, 39.5, 26.8 (3C), 19.0, 18.1 (6C), 12.6 (3C); HRMS (ESI) calcd for $C_{37}H_{57}NO_6Si_2Na$ [(M + Na)$^+$] 690.3617, found 690.3590.

(−)-32. According to **GP1**, (−)-**32** was prepared from (−)-**6** and 3-(2-propenoyl)-2-oxazolidinone: $[\alpha]^{24}_D$ −10.3 (c 0.30, $CHCl_3$); IR (film) 3566, 1772, 1716, 1684, 1362 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.34−7.16 (m, 6H), 7.18 (ddd, J = 15.1, 8.2, 8.2 Hz, 1H), 4.53 (s, 2H), 4.40 (dd, J = 8.3, 7.6 Hz, 2H), 4.25 (m, 1H), 4.04 (dd, J = 8.3, 7.6 Hz, 2H), 3.94 (m, 1H), 3.44 (dd, J = 9.7, 3.4 Hz, 1H), 3.31 (dd, J = 9.7, 7.2 Hz, 1H), 2.67 (s, 1H), 2.62 (m, 1H), 2.54 (m, 1H), 1.67 (ddd, J = 14.1, 9.6, 5.5 Hz, 1H), 1.59 (ddd, J = 14.1, 6.8, 3.1 Hz, 1H), 1.08−1.01 (m, 21H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 165.0, 153.5, 147.3, 138.1, 128.5 (2C), 127.8 (3C), 122.4, 74.8, 73.4, 69.6, 68.0, 62.1, 42.7, 40.1, 39.9, 18.2 (6C), 12.7 (3C); HRMS (ESI) calcd for $C_{27}H_{43}NNaO_6Si$ [(M + Na)$^+$] 528.2752, found 528.2745.

(+)-33. According to **GP1**, (+)-**33** was prepared from (+)-**7** and 3-(2-propenoyl)-2-oxazolidinone: $[\alpha]^{24}_D$ +7.9 (c 0.10, $CHCl_3$); IR (film) 3088, 1797, 1713, 742 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.65−7.63 (m, 4H), 7.41−7.33 (m, 6H), 7.27 (d, J = 15.1 Hz, 1H), 7.06 (ddd, J = 15.1, 7.9, 7.7 Hz, 1H), 4.43−4.31 (m, 2H), 4.06−3.95 (m, 3H), 3.89 (m, 1H), 3.72−3.61 (m, 2H), 3.24 (s, 1H), 2.63 (ddd, J = 14.1, 7.7, 1.4 Hz, 1H), 2.56 (ddd, J = 14.1, 7.9, 1.1 Hz, 1H), 1.66 (m, 1H), 1.58−1.48 (m, 3H), 1.41 (m, 1H), 1.02 (s, 9H), 0.95 (d, J = 7.2 Hz, 3H), 0.88 (s, 9H), 0.10 (s, 3H), 0.09 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 164.8, 153.5, 146.8 (2C), 135.6 (4C), 134.0, 129.5 (2C), 127.6 (4C), 122.3, 77.2, 70.2, 64.0, 62.0, 42.6, 40.0, 38.5, 31.2, 29.3, 26.8 (3C), 25.8 (3C), 19.2, 17.9, 10.9, −4.4, −4.7; HRMS (ESI) calcd for $C_{36}H_{55}NO_6Si_2Na$ [(M + Na)$^+$] 676.3460, found 676.3452.

(−)-34. According to **GP1**, (−)-**34** was prepared from (+)-**9** and 3-(2-propenoyl)-2-oxazolidinone: $[\alpha]^{24}_D$ −3.3 (c 0.50, $CHCl_3$); IR (film) 3424, 2926, 1774, 1682, 1363, 1039, 707 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.26 (d, J = 15.5 Hz, 1H), 7.17 (ddd, J = 15.5, 7.3, 6.9 Hz, 1H), 4.41 (dd, J = 8.6, 7.6 Hz, 2H), 4.07−4.02 (m, 3H), 3.92 (m, 1H), 3.68 (m, 1H), 3.33 (m, 1H), 2.98 (dd, J = 8.9, 2.0 Hz, 1H), 2.61 (dddd, J = 14.8, 8.3, 7.3, 1.0 Hz, 1H), 2.55 (dddd, J = 14.8, 6.9, 5.2, 1.0 Hz, 1H), 2.41 (m, 1H), 2.26 (br s, 1H), 2.12 (m, 1H), 1.71−1.62 (m, 2H), 1.41 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 165.1, 153.5, 147.7, 122.2, 82.5, 69.0, 67.8, 66.2, 62.1, 42.7, 37.1, 32.7, 25.4; HRMS (ESI) calcd for $C_{13}H_{19}NO_6Na$ [(M + Na)$^+$] 308.1105, found 308.1104.

(+)-35. According to **GP1**, (+)-**35** was prepared from (+)-**10** and 3-(2-propenoyl)-2-oxazolidinone: $[\alpha]^{23}_D$ +23.1 (c 0.20, $CHCl_3$); IR (film) 3420, 2926, 1772, 1683, 1362, 1038, 706 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.27 (d, J = 15.5 Hz, 1H), 7.16 (ddd, J = 15.5, 7.3, 6.9 Hz, 1H), 4.41 (dd, J = 8.2, 7.9 Hz, 2H), 4.05 (dd, J = 8.2, 7.9 Hz, 2H), 3.94−3.86 (m, 2H), 3.59 (m, 1H), 3.30 (m, 1H), 2.96 (dd, J = 8.3, 7.9 Hz, 1H), 2.73 (m, 1H), 2.73 (m, 1H), 2.49 (m, 1H), 2.10 (m, 1H), 1.71−1.57 (m, 3H), 1.43 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 165.0, 153.6, 147.2, 122.8, 81.9, 73.8, 70.7, 67.7, 62.1, 42.7, 36.8, 32.4,

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25.2; HRMS (ESI) calcd for $C_{13}H_{19}NO_6Na$ [(M + Na)$^+$] 308.1105, found 308.1099.

(±)-36. According to **GP1**, (±)-**36** was prepared from (±)-**1** and 1-(2-propenoyl)-2,5-dimethylpyrrole: IR (film) 3482, 2927, 1692, 1635, 1538, 1366, 1249 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.25−7.21 (m, 2H), 7.13 (ddd, J = 13.7, 6.9, 6.8 Hz, 1H), 6.88−6.84 (m, 2H), 7.13 (d, J = 13.7 Hz, 1H), 5.82−5.79 (m, 2H), 4.43 (s, 2H), 3.83−3.77 (m, 4H), 3.68 (m, 1H), 3.60 (m, 1H), 3.04 (br s, 1H), 2.32−2.26 (m, 8H), 1.75−1.40 (m, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.4, 159.3, 150.8, 129.8 (2C), 129.3 (2C), 125.5 (2C), 113.8 (2C), 110.5 (2C), 73.0, 71.3, 69.0, 55.2, 36.8, 36.3, 32.5, 23.9, 15.5 (2C); HRMS (ESI) calcd for $C_{23}H_{31}NO_4Na$ [(M + Na)$^+$] 408.2145, found 408.2156.

(−)-37. According to **GP1**, (−)-**37** was prepared from (−)-**5** and 1-(2-propenoyl)-2,5-dimethylpyrrole: $[\alpha]^{28}_D$ −4.1 (c 1.00, $CHCl_3$); IR (film) 3750, 2941, 1698, 1541, 1457, 1363, 702 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.66−7.62 (m, 4H), 7.43−7.34 (m, 6H), 7.04 (ddd, J = 15.1, 7.3, 7.2 Hz, 1H), 6.38 (d, J = 15.1 Hz, 1H), 5.82−5.80 (m, 2H), 4.32 (dddd, J = 7.2, 7.2, 4.1, 4.1 Hz, 1H), 4.16 (m, 1H), 3.85−3.77 (m, 2H), 3.52 (br s, 1H), 2.67−2.54 (m, 2H), 2.30 (s, 6H), 1.74−1.67 (m, 2H), 1.61−1.53 (m, 2H), 1.12−1.00 (m, 30H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.9, 146.8, 135.5 (4C), 133.1 (2C), 129.9, 129.8, 127.7 (4C), 127.5, 110.7 (2C), 69.4, 67.4, 62.8, 43.8, 40.8, 39.5, 26.8 (3C), 19.0, 18.2 (6C), 18.1, 15.5 (3C), 12.6 (3C); HRMS (ESI) calcd for $C_{40}H_{61}NO_4Si_2Na$ [(M + Na)$^+$] 698.4031, found 698.4054.

(−)-38. According to **GP1**, (−)-**38** was prepared from (−)-**6** and 1-(2-propenoyl)-2,5-dimethylpyrrole: $[\alpha]^{28}_D$ −5.0 (c 1.00, $CHCl_3$); IR (film) 3649, 2942, 1697, 1366, 1059 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.35−7.26 (m, 5H), 7.08 (ddd, J = 15.1, 7.9, 7.9 Hz, 1H), 6.39 (d, J = 15.1 Hz, 1H), 5.81 (s, 2H), 4.53 (s, 2H), 4.27 (m, 1H), 3.95 (m, 1H), 3.42 (m, 1H), 3.31 (m, 1H), 2.68−2.52 (m, 2H), 2.29 (s, 6H), 1.69 (m, 1H), 1.62−1.53 (m, 2H), 1.08−1.01 (m, 21H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.9, 147.3, 137.8, 129.8 (2C), 128.5 (2C), 127.8 (3C), 127.6, 110.6 (2C), 74.7, 73.4, 69.3, 67.8, 39.9, 39.6, 18.1 (6C), 15.5 (2C), 12.5 (3C); HRMS (ESI) calcd for $C_{30}H_{47}NO_4SiNa$ [(M + Na)$^+$] 536.3167, found 536.3163.

(+)-39. According to **GP1**, (+)-**39** was prepared from (+)-**7** and 1-(2-propenoyl)-2,5-dimethylpyrrole: $[\alpha]^{28}_D$ +1.3 (c 1.00, $CHCl_3$); IR (film) 3649, 1698, 1541, 1404, 1365, 1263, 996 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.66−7.62 (m, 4H), 7.41 − 7.33 (m, 6H), 6.94 (ddd, J = 15.1, 7.6, 7.6 Hz, 1H), 6.37 (d, J = 15.1 Hz, 1H), 5.82 (s, 2H), 4.00−3.91 (m, 2H), 3.72−3.61 (m, 2H), 3.29 (br s, 1H), 2.67 (m, 1H), 2.58 (m, 1H), 2.30 (s, 6H), 1.71−1.49 (m, 3H), 1.41 (m, 1H), 1.25 (m, 1H), 1.02 (s, 9H), 0.98 (d, J = 7.2 Hz, 3H), 0.89 (s, 9H), 0.11 (s, 3H), 0.10 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.7, 146.3 (2C), 135.5 (4C), 133.9, 129.8 (2C), 129.5 (2C), 127.6 (4C), 127.4, 110.9 (2C), 76.7, 70.2, 64.0, 40.2, 38.5, 31.5, 29.3, 26.8 (3C), 25.8 (3C), 19.2, 17.9, 15.5 (2C), 10.8, −4.4, −4.8; HRMS (ESI) calcd for $C_{39}H_{59}NO_4Si_2Na$ [(M + Na)$^+$] 684.3875, found 684.3886.

(+)-40. According to **GP1**, (+)-**40** was prepared from (+)-**8** and 1-(2-propenoyl)-2,5-dimethylpyrrole: $[\alpha]^{23}_D$ +17.8 (c 1.00, $CHCl_3$); IR (film) 3445, 1694, 1540, 1366, 1257, 1096 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$, a 6:1 mixture of E/Z isomers) δ 7.05 (ddd, J = 15.1, 6.9, 6.8 Hz, 6/7H), 6.40 (m, 1/7H), 6.35 (d, J = 15.5 Hz, 6/7H), 6.23 (d, J = 11.3 Hz, 1/7H), 5.80 (s, 2H), 3.87 (m, 1H), 3.35 (m, 2/7H), 3.32−3.25 (m, 12/7H), 2.99 (ddd, J = 8.9, 8.9, 2.4 Hz, 1H), 2.74 (m, 1/7H), 2.59 (m, 1/7H), 2.51 (m, 6/7H), 2.37 (m, 6/7H), 2.33−2.29 (m, 6H), 2.12−2.03 (m, 13/7H), 1.99 (m, 1/7H), 1.72−1.51 (m, 4H), 1.38 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$, signals with asterisk diagnostic for Z isomer) δ 167.5, 150.9, 150.1*, 130.0 (2C)*, 129.9 (2C), 125.4, 124.4*, 110.8 (2C)*, 110.6 (2C), 81.8*, 81.4, 70.4, 69.9*, 67.6, 33.2, 30.3, 28.6, 25.6, 15.7 (2C)*, 15.5 (2C); HRMS (ESI) calcd for $C_{16}H_{23}NO_3Na$ [(M + Na)$^+$] 300.1570, found 300.1581.

(+)-41. According to **GP1**, (+)-**41** was prepared from (+)-**9** and 1-(2-propenoyl)-2,5-dimethylpyrrole: $[\alpha]^{25}_D$ +6.2 (c 0.50, $CHCl_3$); IR (film) 3649, 2925, 1698, 1541, 1457, 1363, 567 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.06 (ddd, J = 15.1, 7.2, 7.2 Hz, 1H), 6.43 (d, J = 15.1 Hz, 1H), 5.83−5.78 (m, 2H), 4.08 (m, 1H), 3.93 (m, 1H), 3.69 (m, 1H), 2.98 (dd, J = 9.2, 1.7 Hz, 1H), 2.65 − 2.51 (m, 2H), 2.34−2.29 (m, 6H), 2.23−2.08 (m, 2H), 1.72− 1.61 (m, 4H), 1.42 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.2, 147.7, 130.0 (2C), 127.4, 110.7 (2C), 82.7, 68.9, 67.8, 66.2, 37.2, 32.7, 25.3, 15.5 (2C); HRMS (ESI) calcd for $C_{16}H_{23}NO_4Na$ [(M + Na)$^+$] 316.1519, found 316.1521.

(+)-42. According to **GP1**, (+)-**42** was prepared from (+)-**10** and 1-(2-propenoyl)-2,5-dimethylpyrrole: $[\alpha]^{29}_D$ +9.1 (c 1.00, $CHCl_3$); IR (film) 3649, 1698, 1653, 1457, 1362, 668 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.08 (ddd, J = 14.8, 7.9, 6.5 Hz, 1H), 6.46 (d, J = 14.8 Hz, 1H), 5.85−5.78 (m, 2H), 4.00−3.85 (m, 2H), 3.60 (m, 1H), 3.29 (m, 1H), 2.98 (m, 1H), 2.73 (m, 1H), 2.50 (m, 1H), 2.34−2.28 (m, 6H), 2.10 (m, 1H), 1.69−1.61 (m, 4H), 1.44 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 167.2, 147.0, 130.0 (2C), 127.9, 110.8 (2C), 82.0, 73.7, 70.9, 67.8, 36.8, 32.7, 25.2, 15.6 (2C); HRMS (ESI) calcd for $C_{16}H_{23}NO_4Na$ [(M + Na)$^+$] 316.1519, found 316.1530.

2,6-*Cis*-Substituted Tetrahydropyrans 29b−g and 43−55. *General Procedure for Intramolecular Oxa-Conjugate Cyclization of α,β-Unsaturated 2-Oxazolidinone Imides and 2,5-Dimethylpyrrole Amides (GP3).* To a solution of α,β-unsaturated 2,5-dimethylpyrrole amides (±)-**28g** (39.0 mg, 0.0770 mmol) in CH_2Cl_2 (1.4 mL) was added CSA (3.6 mg, 0.015 mmol), and the resultant solution was stirred at room temperature for 24 h. The reaction was quenched with Et_3N, and the resultant mixture was concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (5 to 10% EtOAc/hexanes) gave tetrahydropyran (±)-**29g** (34.6 mg, 90%) as a colorless oil.

(±)-29b. According to **GP3**, (±)-**29b** was prepared from (±)-**28b**: IR (film) 3648, 2930, 1734, 1698, 1362, 1110, 703 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.66−7.62 (m, 4H), 7.41−7.33 (m, 6H), 3.81 (dddd, J = 13.2, 7.2, 5.5, 1.8 Hz, 1H), 3.77−3.66 (m, 4H), 3.49 (m, 1H), 3.11 (dd, J = 16.1, 7.2 Hz, 1H), 2.97 (dd, J = 16.1, 5.5 Hz, 1H), 2.58 (dd, J = 8.3, 7.9 Hz, 2H), 1.95−1.87 (m, 2H), 1.81−1.71 (m, 2H), 1.67−1.60 (m, 2H), 1.56−1.47 (m, 2H), 1.26−1.11 (m, 2H), 1.01 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 175.2, 171.8, 135.5 (4C), 134.1 (2C), 129.5 (2C), 127.6 (4C), 74.7, 73.8, 60.6, 45.4, 43.5, 39.3, 33.7, 31.4, 31.3, 26.8 (3C), 23.5, 19.2, 17.1; HRMS (ESI) calcd for $C_{29}H_{39}NO_4SiNa$ [(M + Na)$^+$] 516.2541, found 516.2541.

(±)-29c. According to **GP3**, (±)-**29c** was prepared from (±)-**28c**: IR (film) 2931, 2857, 1782, 1702, 1388, 1196, 1110, 704 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.65−7.62 (m, 4H), 7.41−7.34 (m, 6H), 4.28−4.20 (m, 2H), 3.86−3.79 (m, 3H), 3.75 (ddd, J = 13.7, 7.6, 6.2 Hz, 1H), 3.69 (ddd, J = 13.7, 6.9, 5.5 Hz, 1H), 3.49 (m, 1H), 3.14 (dd, J = 15.8, 7.9 Hz, 1H), 2.95 (dd, J = 15.8, 5.2 Hz, 1H), 1.80 (m, 1H), 1.73 (m, 1H), 1.68−1.61 (m, 2H), 1.60−1.48 (m, 2H), 1.28−1.12 (m, 2H), 1.02 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.9, 153.4, 135.5 (4C), 134.1, 134.0, 129.5 (2C), 127.6 (4C), 74.7, 73.8, 61.9, 60.5, 42.4, 41.8, 39.3, 31.3, 31.2, 26.8 (3C), 23.5, 19.8; HRMS (ESI) calcd for $C_{28}H_{37}NO_5SiNa$ [(M + Na)$^+$] 518.2333, found 518.2318.

(±)-29d. According to **GP3**, (±)-**29d** was prepared from (±)-**28d**: IR (film) 2965, 1859, 1739, 1479, 820, 747 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.99 (m, 1H), 7.65−7.57 (m, 4H), 7.42−7.30 (m, 6H), 7.25−7.14 (m, 3H), 3.93 (m, 1H), 3.72 (ddd, J = 16.5, 6.2, 4.1 Hz, 1H), 3.66 (ddd, J = 16.5, 6.5, 4.8 Hz, 1H), 3.52 (m, 1H), 3.29 (dd, J = 16.5, 7.6 Hz, 1H), 3.16 (dd, J = 16.5, 5.2 Hz, 1H), 1.84 (m, 1H), 1.74−1.68 (m, 2H), 1.67−1.51 (m, 3H), 1.31 (m, 1H), 1.20 (m, 1H), 0.99 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.0, 151.3, 142.3, 135.5 (4C), 134.1, 129.4 (2C), 127.7 (2C), 127.5 (4C), 125.1, 124.7, 116.0, 109.7, 74.8, 73.3, 60.4, 43.4, 39.3, 31.3, 26.8 (3C), 26.5, 23.5, 19.2; HRMS (ESI) calcd for $C_{32}H_{37}NNaO_5Si$ [(M + Na)$^+$] 566.2333, found 566.2323.

(±)-29e. According to **GP3**, (±)-**29e** was prepared from (±)-**28e**: IR (film) 2931, 1699, 1454, 1351, 1206, 1110, 702 cm^{-1}; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.45 (d, J = 7.8 Hz, 1H), 7.61−7.57 (m, 4H), 7.52 (d, J = 7.8 Hz, 1H), 7.45 (d, J = 3.6 Hz, 1H), 7.39−7.25 (m, 8H), 6.49 (d, J = 3.6 Hz, 1H), 3.91 (m, 1H), 3.72−3.61 (m, 2H), 3.56 (m, 1H), 3.07 (dd, J = 15.0, 6.0 Hz, 1H), 2.87 (dd, J = 15.0, 6.0 Hz, 1H), 1.86−1.78 (m, 2H), 1.72−1.62 (m, 2H), 1.62−1.52 (m, 2H), 1.32−1.14 (m, 2H), 0.99 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 169.6, 135.6, 135.5 (4C), 134.1, 133.9, 130.4, 129.5 (2C), 127.5 (4C), 125.5, 124.9, 123.6, 120.7, 116.7, 108.7, 74.8, 74.3, 60.2, 43.1, 39.3, 31.6, 31.4, 26.8 (3C), 23.4, 19.2; HRMS (ESI) calcd for $C_{33}H_{39}NO_3SiNa$ [(M + Na)$^+$] 548.2591, found 548.2600.

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(±)-**29f.** According to **GP3**, (±)-**29f** was prepared from (±)-**28f**: IR (film) 3647, 2930, 1652, 1264, 1360, 1111, 702 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 8.21 (d, J = 7.8 Hz, 1H), 7.62−7.59 (m, 4H), 7.40−7.29 (m, 6H), 7.20−7.11 (m, 2H), 7.00 (dd, J = 7.8, 7.2 Hz, 1H), 4.12−3.96 (m, 2H), 3.88 (m, 1H), 3.76−3.66 (m, 2H), 3.55 (m, 1H), 3.12−3.01 (m, 2H), 2.64 (dd, J = 15.0, 6.6 Hz, 1H), 2.44 (dd, J = 15.0, 6.0 Hz, 1H), 1.84−1.78 (m, 2H), 1.75−1.62 (m, 2H), 1.62−1.52 (m, 2H), 1.25−1.12 (m, 2H), 0.99 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 169.3, 142.9, 135.5 (4C), 134.0, 133.9, 131.3, 129.5, 128.3, 127.5 (4C), 127.4, 124.5, 123.6, 117.1, 75.0, 74.8, 60.4, 48.3, 43.1, 39.4, 31.7, 31.5, 27.9, 26.8 (3C), 23.4, 19.2; HRMS (ESI) calcd for $C_{33}H_{42}NO_3Si$ [$(M + H)^+$] 528.2928, found 528.2938.

(±)-**29g.** IR (film) 2930, 1715, 1540, 1364, 1111, 702 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.66−7.61 (m, 4H), 7.41−7.31 (m, 6H), 5.80−5.76 (m, 2H), 3.89 (m, 1H), 3.77−3.66 (m, 2H), 3.52 (m, 1H), 2.96 (dd, J = 16.9, 6.2 Hz, 1H), 2.75 (dd, J = 16.9, 6.5 Hz, 1H), 2.34−2.31 (m, 6H), 1.81 (m, 1H), 1.74−1.51 (m, 5H), 1.24−1.11 (m, 2H), 1.02 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.6, 135.5 (4C), 134.1, 134.0, 130.3 (2C), 129.5 (2C), 127.5 (4C), 111.3, 111.2, 74.9, 74.6, 60.4, 45.8, 39.4, 31.4 (2C), 26.9 (3C), 23.4, 19.2, 16.5 (2C); HRMS (ESI) calcd for $C_{31}H_{41}NO_3SiNa$ [$(M + Na)^+$] 526.2748, found 526.2754.

(±)-**43.** According to **GP3**, (±)-**43** was prepared from (±)-**30** (reaction time: 23 h): IR (film) 2924, 1780, 1702, 1510, 1388, 1248, 1038 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 7.25 (d, J = 8.2 Hz, 2H), 6.81 (d, J = 8.2 Hz, 2H), 4.37 (s, 2H), 3.99 (m, 1H), 3.62 (m, 1H), 3.56−3.50 (m, 2H), 3.42 (dd, J = 16.1, 7.6 Hz, 1H), 3.30 (s, 3H), 3.06−2.91 (m, 5H), 1.87 (m, 1H), 1.75 (m, 1H), 1.57−1.48 (m, 2H), 1.34−1.26 (m, 2H), 1.17 (m, 1H), 1.09 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.9, 159.1, 153.5, 130.8, 129.2 (2C), 113.7 (2C), 74.9, 73.8, 72.6, 66.6, 61.9, 55.3, 42.5, 41.9, 36.5, 31.3, 31.2, 23.5; HRMS (ESI) calcd for $C_{20}H_{27}NO_6Na$ [$(M + Na)^+$] 400.1731, found 400.1727.

(+)-**44.** According to **GP3**, (+)-**44** was prepared from (−)-**31** (reaction time: 9 h): $[\alpha]^{24}_D$ +4.8 (c 1.00, $CHCl_3$); IR (film) 3567, 2942, 1784, 1700, 1387, 1225, 1111, 882, 703 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.66−7.62 (m, 4H), 7.41−7.33 (m, 6H), 4.30−4.21 (m, 2H), 3.90−3.83 (m, 3H), 3.79 (m, 1H), 3.76−3.67 (m, 2H), 3.49 (m, 1H), 3.21 (dd, J = 16.4, 7.9 Hz, 1H), 2.95 (dd, J = 16.4, 4.8 Hz, 1H), 1.98−1.85 (m, 2H), 1.81−1.63 (m, 2H), 1.31−1.19 (m, 2H), 1.05−0.99 (m, 30H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.7, 153.4, 135.5 (4C), 134.0 (2C), 129.5 (2C), 127.5 (4C), 72.5, 71.4, 68.5, 61.9, 60.8, 60.5, 42.4, 41.5, 38.8, 26.8 (3C), 19.2, 18.1 (6C), 12.3 (3C), 12.2; HRMS (ESI) calcd for $C_{37}H_{57}NO_6Si_2Na$ [$(M + Na)^+$] 690.3617, found 690.3607.

(−)-**45.** According to **GP3**, (−)-**45** was prepared from (−)-**32** (reaction time: 5 h): $[\alpha]^{24}_D$ −2.9 (c 1.00, $CHCl_3$); IR (film) 2942, 2865, 1781, 1703, 1387, 1206, 1101, 882, 680 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.31−7.29 (m, 3H), 7.26−7.22 (m, 2H), 4.55 (d, J = 12.0 Hz, 1H), 4.53 (d, J = 12.0 Hz, 1H), 4.42 (m, 1H), 4.35−4.27 (m, 3H), 4.12 (m, 1H), 4.00−3.92 (m, 2H), 3.47−3.40 (m, 2H), 3.26 (dd, J = 16.1, 8.2 Hz, 1H), 2.92 (d, J = 16.1, 4.4 Hz, 1H), 1.72 (m, 1H), 1.59 (m, 1H), 1.53−1.46 (m, 2H), 1.10−1.01 (m, 21H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.8, 153.4, 138.6, 128.3 (2C), 127.5 (2C), 127.4, 73.5, 73.1, 71.4, 68.2, 64.8, 61.9, 42.5, 41.5, 39.1, 35.6, 18.1 (6C), 12.2 (3C); HRMS (ESI) calcd for $C_{27}H_{43}NO_6SiNa$ [$(M + Na)^+$] 528.2752, found 528.2754.

(−)-**46.** According to **GP3**, (−)-**46** was prepared from (+)-**33** (reaction time: 7 h): $[\alpha]^{24}_D$ −12.5 (c 1.00, $CHCl_3$); IR (film) 2929, 2856, 1785, 1704, 1387, 1224, 1109, 702 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 7.66−7.62 (m, 4H), 7.42−7.38 (m, 2H), 7.37−7.34 (m, 4H), 4.36−4.29 (m, 2H), 3.95 (dd, J = 8.6, 7.6 Hz, 2H), 3.83−3.77 (m, 2H), 3.66 (ddd, J = 16.1, 10.3, 6.2 Hz, 1H), 3.62 (ddd, J = 16.5, 10.3, 6.5 Hz, 1H), 3.25 (m, 1H), 3.24 (dd, J = 16.5, 8.2 Hz, 1H), 2.92 (dd, J = 16.4, 4.1 Hz, 1H), 1.66 (m, 1H), 1.62−1.51 (m, 4H), 1.49−1.39 (m, 2H), 1.02 (s, 9H), 0.87 (s, 9H), 0.81 (d, J = 6.9 Hz, 3H), 0.03 (s, 3H), 0.03 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.7, 153.4, 135.5 (4C), 134.0 (2C), 129.5 (2C), 127.6 (4C), 78.6, 71.8, 71.4, 63.8, 62.0, 42.5, 41.3, 38.9, 35.6, 29.1 (2C), 26.9 (3C), 25.8, 19.2, 18.0, 5.0 (3C), −4.6 (2C); HRMS (ESI) calcd for $C_{36}H_{55}NO_6Si_2Na$ [$(M + Na)^+$] 676.3460, found 676.3461.

(+)-**47.** According to **GP3**, (+)-**47** was prepared from (−)-**34** (reaction time: 23 h): $[\alpha]^{22}_D$ +6.2 (c 1.00, $CHCl_3$); IR (film) 3549, 2939, 1779, 1697, 1389, 1227, 1099, 959, 708 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 4.46−4.35 (m, 2H), 4.06−3.96 (m, 3H), 3.92 (m, 1H), 3.73 (dddd, J = 11.0, 6.5, 4.8, 2.1 Hz, 1H), 3.37 (m, 1H), 3.30 (dd, J = 16.9, 7.9 Hz, 1H), 3.07 (ddd, J = 13.4, 8.6, 4.4 Hz, 1H), 2.95 (dd, J = 16.9, 4.4 Hz, 1H), 2.83 (dd, J = 11.0, 8.6 Hz, 1H), 2.44 (d, J = 2.1 Hz, 1H), 2.08 (ddd, J = 12.7, 5.2, 2.0 Hz, 1H), 2.01 (m, 1H), 1.71−1.65 (m, 2H), 1.51 (m, 1H), 1.42 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.3, 153.4, 83.8, 74.9, 71.2, 70.2, 67.8, 62.1, 42.4, 41.0, 38.5, 29.1, 25.4; HRMS (ESI) calcd for $C_{13}H_{19}NO_6Na$ [$(M + Na)^+$] 308.1105, found 308.1098.

(−)-**48.** According to **GP3**, (−)-**48** was prepared from (+)-**35** (reaction time: 22 h): $[\alpha]^{23}_D$ −6.5 (c 1.00, $CHCl_3$); IR (film) 3566, 2923, 1773, 1698, 1388, 1226, 1098, 959, 701 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 4.42−4.33 (m, 3H), 4.08 (m, 1H), 4.00 (m, 1H), 3.91 (m, 1H), 3.61 (ddd, J = 10.3, 9.3, 3.8 Hz, 1H), 3.44 (ddd, J = 10.7, 10.7, 4.5 Hz, 1H), 3.25 (dd, J = 16.8, 8.3 Hz, 1H), 2.99 (dd, J = 9.3, 2.1 Hz, 1H), 2.84 (dd, J = 16.8, 3.4 Hz, 1H), 2.44 (m, 1H), 2.01 (m, 1H), 1.93 (m, 1H), 1.73−1.60 (m, 4H), 1.39 (dddd, J = 11.3, 11.3, 10.3, 5.5 Hz, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.3, 153.5, 79.7, 70.6, 68.2, 67.8, 65.8, 62.0, 42.4, 40.8, 37.3, 29.4, 25.5; HRMS (ESI) calcd for $C_{13}H_{19}NO_6Na$ [$(M + Na)^+$] 308.1105, found 308.1097.

(±)-**49.** According to **GP3**, (±)-**49** was prepared from (±)-**36** (reaction time: 30 h): IR (film) 2931, 1714, 1513, 1365, 1248, 1089 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.22 (d, J = 8.6 Hz, 2H), 6.84 (d, J = 8.6 Hz, 2H), 5.80 (s, 2H), 4.38 (s, 2H), 3.93 (m, 1H), 3.77 (s, 3H), 3.51−3.44 (m, 3H), 3.42 (dd, J = 15.8, 7.2 Hz, 1H), 2.76 (dd, J = 15.8, 5.5 Hz, 1H), 2.37 (s, 6H), 1.82 (m, 1H), 1.73−1.51 (m, 5H), 1.27−1.13 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.6, 159.1, 130.7, 130.3 (2C), 129.3 (2C), 113.7 (2C), 111.2 (2C), 75.1, 74.6, 72.6, 66.5, 55.2, 45.7, 36.5, 31.4 (2C), 23.4, 16.5 (2C); HRMS (ESI) calcd for $C_{23}H_{31}NO_4Na$ [$(M + Na)^+$] 408.2145, found 408.2136.

(+)-**50.** According to **GP3**, (+)-**50** was prepared from (−)-**37** (reaction time: 5.5 h): $[\alpha]^{26}_D$ +7.6 (c 0.50, $CHCl_3$); IR (film) 2928, 1716, 1684, 1541, 1457, 1112, 701, 538 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.63−7.60 (m, 4H), 7.39−7.31 (m, 6H), 5.78 (s, 2H), 3.91−3.85 (m, 2H), 3.75−3.67 (m, 2H), 3.51 (m, 1H), 3.01 (dd, J = 16.1, 6.9 Hz, 1H), 2.75 (dd, J = 16.1, 5.9 Hz, 1H), 2.32 (s, 6H), 2.00 (m, 1H), 1.88 (m, 1H), 1.73 (m, 1H), 1.65 (m, 1H), 1.25−1.17 (m, 2H), 1.06−0.99 (m, 30H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.3, 135.5 (4C), 134.0, 133.9, 130.2 (2C), 129.5 (2C), 127.6 (4C), 111.2 (2C), 72.7, 72.3, 68.4, 60.4, 45.3, 41.8, 41.6, 38.9, 30.9, 26.8 (3C), 19.2, 18.1 (6C), 16.4, 12.3 (3C); HRMS (ESI) calcd for $C_{40}H_{61}NO_4Si_2Na$ [$(M + Na)^+$] 698.4031, found 698.4011

(−)-**51.** According to **GP3**, (−)-**51** was prepared from (−)-**38** (reaction time: 4.5 h): $[\alpha]^{29}_D$ −9.0 (c 1.00, $CHCl_3$); IR (film) 2865, 1715, 1541, 1457, 1364, 1042, 676, 519 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.31−7.27 (m, 3H), 7.26−7.22 (m, 2H), 5.78 (s, 2H), 4.54−4.44 (m, 3H), 4.32 (m, 1H), 4.10 (m, 1H), 3.45−3.39 (m, 2H), 3.08 (dd, J = 15.8, 7.2 Hz, 1H), 2.78 (dd, J = 15.8, 5.8 Hz, 1H), 2.35 (s, 6H), 1.76 (m, 1H), 1.61 (m, 1H), 1.53−1.45 (m, 2H), 1.09−1.02 (m, 21H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.4, 138.5, 130.1 (2C), 128.3 (2C), 127.6 (2C), 127.4, 110.0 (2C), 73.4, 73.2, 71.5, 69.3, 64.8, 45.5, 39.1, 35.7, 18.1 (6C), 16.3 (2C), 12.2 (3C); HRMS (ESI) calcd for $C_{30}H_{47}NO_4SiNa$ [$(M + Na)^+$] 536.3167, found 536.3154.

(−)-**52.** According to **GP3**, (−)-**52** was prepared from (+)-**39** (reaction time: 3 h): $[\alpha]^{27}_D$ −13.7 (c 1.00, $CHCl_3$); IR (film) 2929, 2856, 1716, 1540, 1507, 1363, 1110, 775, 505 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 7.66−7.61 (m, 4H), 7.41−7.32 (m, 6H), 5.79 (s, 2H), 3.90 (m, 1H), 3.82 (m, 1H), 3.67−3.56 (m, 2H), 3.27 (m, 1H), 3.04 (dd, J = 15.8, 7.2 Hz, 1H), 2.75 (dd, J = 15.8, 4.8 Hz, 1H), 2.35 (s, 6H), 1.67 (m, 1H), 1.63−1.49 (m, 4H), 1.47−1.36 (m, 2H), 1.02 (s, 9H), 0.87 (s, 9H), 0.81 (d, J = 6.8 Hz, 3H), 0.04 (s, 3H), 0.03 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.4, 135.6 (4C), 134.0 (2C), 130.2 (2C), 129.5 (2C), 127.6 (4C), 111.2 (2C), 78.8, 72.8, 71.3, 63.8, 42.5, 38.8, 35.7, 29.0 (2C), 26.9 (3C), 25.8, 19.2, 18.0, 16.4 (2C), 5.0 (3C), −4.6, −4.7; HRMS (ESI) calcd for $C_{39}H_{59}NO_4Si_2Na$ [$(M + Na)^+$] 684.3875, found 684.3890.

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(−)-**53.** According to **GP3**, (−)-**53** was prepared from (+)-**40** (reaction time: 7 h): $[\alpha]^{24}_{D}$ −25.4 (*c* 1.00, $CHCl_3$); IR (film) 3734, 1716, 1541, 1507, 1457, 1099, 773 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 5.80 (s, 2H), 4.01 (m, 1H), 3.87 (m, 1H), 3.37 (ddd, *J* = 11.9, 11.9, 2.8 Hz, 1H), 3.11−3.04 (m, 2H), 2.94 (m, 1H), 2.79 (dd, *J* = 16.0, 5.5 Hz, 1H), 2.36 (s, 6H), 2.01−1.88 (m, 3H), 1.76−1.63 (m, 2H), 1.58−1.35 (m, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.3, 130.3 (2C), 111.3 (2C), 78.3, 78.1, 74.2, 68.0, 45.1, 31.1, 29.6, 29.4, 25.7, 16.5 (2C); HRMS (ESI) calcd for $C_{16}H_{23}NO_3Na$ $[(M + Na)^+]$ 300.1570, found 300.1580.

(−)-**54.** According to **GP3**, (−)-**54** was prepared from (+)-**41** (reaction time: 3 h): $[\alpha]^{26}_{D}$ −5.9 (*c* 0.50, $CHCl_3$); IR (film) 3735, 1716, 1541, 1507, 1457, 1102, 960 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 5.80 (s, 2H), 4.12 (m, 1H), 3.92 (m, 1H), 3.76 (ddd, *J* = 11.0, 8.9, 5.2 Hz, 1H), 3.36 (m, 1H), 3.14−3.07 (m, 2H), 2.85−2.79 (m, 2H), 2.36 (s, 6H), 2.18 (ddd, *J* = 12.7, 5.2, 2.0 Hz, 1H), 2.01 (m, 1H), 1.71−1.66 (m, 3H), 1.49−1.38 (m, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.9, 130.3 (2C), 111.5 (2C), 83.8, 74.9, 72.3, 70.2, 67.9, 44.7, 38.5, 29.1, 25.4, 16.6 (2C); HRMS (ESI) calcd for $C_{16}H_{23}NO_4Na$ $[(M + Na)^+]$ 316.1519, found 316.1511.

(−)-**55.** According to **GP3**, (−)-**55** was prepared from (+)-**42** (reaction time: 6 h): $[\alpha]^{28}_{D}$ −18.9 (*c* 1.00, $CHCl_3$); IR (film) 3649, 1698, 1653, 1363, 1339, 669 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 5.78 (s, 2H), 4.44 (m, 1H), 4.10 (dd, *J* = 5.8, 3.1 Hz, 1H), 3.92 (m, 1H), 3.62 (dddd, *J* = 9.6, 5.2, 4.4, 4.1 Hz, 1H), 3.44 (ddd, *J* = 11.3, 11.3, 3.4 Hz, 1H), 3.03−2.98 (m, 2H), 2.76 (dd, *J* = 15.8, 5.2 Hz, 1H), 2.36 (s, 6H), 2.05−1.97 (m, 2H), 1.71−1.58 (m, 4H), 1.37 (m, 1H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 172.1, 130.2 (2C), 111.2 (2C), 79.8, 70.8, 69.0, 68.2, 65.8, 44.7, 37.4, 29.4, 25.5, 16.4 (2C); HRMS (ESI) calcd for $C_{16}H_{23}NO_4Na$ $[(M + Na)^+]$ 316.1519, found 316.1510.

2,6-*Trans*-Substituted Tetrahydropyran (−)-*trans*-24. To a solution of α,β-unsaturated thioester (+)-**17** (52.1 mg, 0.0754 mmol) in THF (0.5 mL) at −78 °C was added a solution of KO*t*-Bu (2.0 mg, 0.018 mmol) in THF (0.3 mL + 0.3 mL rinse), and the resultant solution was stirred at −78 °C for 1.5 h. To the resultant solution was added a solution of KO*t*-Bu (2.0 mg, 0.018 mmol) in THF (0.2 mL + 0.2 mL rinse), and the resultant solution was stirred at −78 °C for 0.5 h. The reaction was quenched with saturated aqueous NH_4Cl solution, and the resultant mixture was extracted with EtOAc. The organic layer was washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (2 to 6% Et_2O/hexanes) gave 2,6-*trans*-substituted tetrahydropyran (−)-*trans*-**24** (35.2 mg, 68%) along with (−)-*cis*-**24** (8.9 mg, 17%). Data for (−)-*trans*-**24**: $[\alpha]^{23}_{D}$ −27.1 (*c* 1.00, $CHCl_3$); IR (film) 2929, 2856, 1706, 1467, 1428, 1253, 1110, 994, 835, 702, 506 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.67−7.65 (m, 4H), 7.41−7.33 (m, 6H), 7.25−7.22 (m, 2H), 7.16−7.13 (m, 2H), 4.40 (m, 1H), 3.92 (ddd, *J* = 6.9, 6.8, 3.4 Hz, 1H), 3.72−3.59 (m, 3H), 2.90 (dd, *J* = 14.4, 8.2 Hz, 1H), 2.66 (dd, *J* = 14.4, 5.5 Hz, 1H), 2.32 (s, 3H), 1.91 (m, 1H), 1.84 (ddd, *J* = 7.2, 3.8, 3.4 Hz, 1H), 1.79−1.70 (m, 2H), 1.53−1.46 (m, 3H), 1.02 (s, 9H), 0.88 (s, 9H), 0.85 (d, *J* = 7.2 Hz, 3H), 0.04 (s, 3H), 0.03 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$, 40 °C) δ 195.1, 139.5, 135.6 (4C), 134.36 (2C), 134.29, 134.25, 130.0 (2C), 129.5 (2C), 127.6 (4C), 124.4, 75.3, 68.6, 65.1, 63.9, 48.2, 38.5, 36.4, 29.5, 26.9 (3C), 26.1, 25.9 (3C), 21.3, 19.3, 18.0, 10.1, −4.5, −4.9; HRMS (ESI) calcd for $C_{40}H_{58}O_4SSi_2Na$ $[(M + Na)^+]$ 713.3487, found 713.3490.

2,6-*Trans*-Substituted Tetrahydropyran (±)-*trans*-29c. Prepared from (±)-**28c** (73% yield) in the same way as that described for (−)-*trans*-**24**: IR (film) 2931, 1782, 1701, 1473, 1387, 1111, 702, 614, 504 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.67−7.62 (m, 4H), 7.41−7.33 (m, 6H), 4.28−4.17 (m, 3H), 3.98 (m, 1H), 3.80−3.66 (m, 4H), 3.31 (dd, *J* = 15.8, 8.6 Hz, 1H), 2.92 (dd, *J* = 15.8, 4.8 Hz, 1H), 1.96 (m, 1H), 1.71−1.60 (m, 5H), 1.42−1.30 (m, 2H), 1.01 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.9, 153.4, 135.6, 134.1, 134.0, 129.5 (2C), 129.4 (2C), 128.3, 127.6 (2C), 127.5 (2C), 68.7, 67.2, 61.9, 60.8, 42.4, 39.4, 35.7, 30.0, 29.6, 26.8 (3C), 19.1, 18.6; HRMS (ESI) calcd for $C_{28}H_{37}O_5SiNNa$ $[(M + Na)^+]$ 518.2333, found 518.2327.

2,6-*Trans*-Substituted Tetrahydropyran (−)-*trans*-52. Prepared from (+)-**39** in the same way as that described for (−)-*trans*-**24**: $[\alpha]^{26}_{D}$ −6.8 (*c* 1.00, $CHCl_3$); IR (film) 2928, 1716, 1541, 1457, 1252, 1110, 835, 702, 503 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.66−7.62 (m, 4H), 7.42−7.32 (m, 6H), 5.76 (s, 2H), 4.42 (m, 1H), 3.92 (m, 1H), 3.65 (m, 1H), 3.61−3.56 (m, 2H), 3.01 (dd, *J* = 15.4, 7.9 Hz, 1H), 2.79 (dd, *J* = 15.4, 5.8 Hz, 1H), 2.35−2.31 (m, 5H), 1.93 (m, 1H), 1.84 (m, 1H), 1.77 (m, 1H), 1.67 (m, 1H), 1.53−1.46 (m, 3H), 1.41 (m, 1H), 1.01 (s, 9H), 0.87 (s, 9H), 0.84 (d, *J* = 6.8 Hz, 3H), 0.020 (s, 3H), 0.019 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$, 40 °C, signals with asterisk only weakly observed) δ 172.3, 135.6 (2C), 135.5 (2C), 134.20, 134.16, 130.0 (2C), 129.4 (2C), 127.5 (4C), 111.3 (2C), 76.3, 68.8, 63.9, 63.3*, 44.4, 38.1, 37.6*, 29.7, 29.4, 26.8 (3C), 25.8 (3C), 19.2, 18.0, 16.4 (2C), 11.6*, −4.6, −5.0; HRMS (ESI) calcd for $C_{39}H_{60}O_4Si_2N$ $[(M + H)^+]$ 662.4043, found 662.4055.

***α,β*-Unsaturated Ester (+)-56.** To a solution of olefin (+)-7 (65.4 mg, 0.121 mmol) in CH_2Cl_2 (0.6 mL) were added methyl acrylate (0.22 mL, 2.4 mmol) and a solution of the Grubbs second-generation catalyst (4.1 mg, 0.0048 mmol) in CH_2Cl_2 (0.6 mL), and the resultant solution was stirred at room temperature for 4 h. To the reaction mixture was added an additional portion of a solution of the Grubbs second-generation catalyst (4.1 mg, 0.0048 mmol) in CH_2Cl_2 (0.4 mL), and the resultant solution was stirred at room temperature for 4 h. To the reaction mixture was added an additional portion of a solution of the Grubbs second-generation catalyst (2.1 mg, 0.0025 mmol) in CH_2Cl_2 (0.4 mL), and the resultant solution was stirred at room temperature for 1 h. After complete consumption of (+)-7, the reaction mixture was stirred at room temperature for 30 min under air and then concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel (0 to 5 to 8 to 10% EtOAc/hexanes) to give α,β-unsaturated ester (+)-**56** (70.8 mg, 98%) as a pale brown oil: $[\alpha]^{23}_{D}$ +10.1 (*c* 1.00, $CHCl_3$); IR (film) 3517, 2952, 2857, 1727, 1428, 1257, 1111, 837, 703, 505 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.66−7.63 (m, 4H), 7.41−7.34 (m, 6H), 6.85 (ddd, *J* = 15.6, 7.8, 7.2 Hz, 1H), 5.84 (ddd, *J* = 15.6, 1.2, 1.2 Hz, 1H), 3.97 (m, 1H), 3.86 (ddd, *J* = 8.4, 5.4, 2.4 Hz, 1H), 3.72−3.60 (m, 5H), 3.32 (br s, 1H), 2.56 (dddd, *J* = 14.4, 8.4, 7.8, 1.2 Hz, 1H), 2.47 (dddd, *J* = 14.4, 7.2, 5.4, 1.2 Hz, 1H), 1.65 (m, 1H), 1.58−1.46 (m, 3H), 1.40 (m, 1H), 1.02 (s, 9H), 0.95 (d, *J* = 7.2 Hz, 3H), 0.88 (s, 9H), 0.09 (s, 3H), 0.08 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 166.6, 144.9, 135.6 (4C), 133.91, 133.89, 129.5 (2C), 127.584 (2C), 127.577 (2C), 123.3, 76.9, 70.1, 63.9, 51.5, 39.5, 38.1, 31.2, 29.2, 26.8 (3C), 25.8 (3C), 19.2, 17.9, 10.9, −4.4, −4.7; HRMS (ESI) calcd for $C_{34}H_{54}O_5Si_2Na$ $[(M + Na)^+]$ 621.3402, found 621.3387.

2,6-*Trans*-Substituted Tetrahydropyran (−)-*trans*-57. Prepared from (+)-**56** in the same way as that described for (−)-*trans*-**24**: $[\alpha]^{22}_{D}$ −18.7 (*c* 1.00, $CHCl_3$); IR (film) 2953, 2857, 1743, 1428, 1254, 1110, 836, 702, 504 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.66−7.35 (m, 4H), 7.41−7.35 (m, 6H), 4.31 (m, 1H), 3.90 (ddd, *J* = 6.9, 3.5, 3.4 Hz, 1H), 3.69 (m, 1H), 3.65−3.59 (m, 5H), 2.58 (dd, *J* = 14.4, 8.6 Hz, 1H), 2.37 (dd, *J* = 14.4, 5.8 Hz, 1H), 1.92 (m, 1H), 1.83 (m, 1H), 1.75 (ddd, *J* = 13.4, 6.5, 3.5 Hz, 1H), 1.69 (m, 1H), 1.52−1.41 (m, 3H), 1.03 (s, 9H), 0.88 (s, 9H), 0.85 (d, *J* = 7.2 Hz, 3H), 0.033 (s, 3H), 0.026 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$, 45 °C) δ 171.6, 135.61 (2C), 135.59 (2C), 134.33, 134.31, 129.5 (2C), 127.6 (4C), 75.3, 68.8, 64.4, 63.9, 51.5, 39.8, 38.5, 36.7, 29.5, 26.9 (3C), 25.9 (4C), 19.3, 18.1, 10.4, −4.6, −4.9; HRMS (ESI) calcd for $C_{34}H_{54}O_5Si_2Na$ $[(M + Na)^+]$ 621.3402, found 621.3402.

Aldehyde (±)-58. To a solution of thioester (±)-**21** (56.3 mg, 0.106 mmol) in CH_2Cl_2 (0.5 mL) were added 10% Pd/C (5.6 mg) and Et_3SiH (0.050 mL, 0.31 mmol), and the resultant mixture was stirred at room temperature for 2 h. Insoluble materials were filtered off, and the filtrate was concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (3 to 7 to 10% EtOAc/hexanes) gave aldehyde (±)-**58** (37.2 mg, 86%) as a colorless oil: IR (film) 2932, 2857, 1727, 1428, 1111, 738, 703, 504 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 9.47 (dd, *J* = 3.0, 1.8 Hz, 1H), 7.81−7.77 (m, 4H), 7.30−7.23 (m, 6H), 3.87 (ddd, *J* = 10.2, 8.4, 5.4 Hz, 1H), 3.75 (ddd, *J* = 10.2, 6.6, 4.8 Hz, 1H), 3.44−3.37 (m, 2H), 2.18 (ddd, *J* = 16.2, 7.8, 3.0 Hz, 1H), 1.92 (ddd, *J* = 16.2, 4.8, 1.8 Hz, 1H), 1.75−1.63 (m, 2H), 1.46 (m, 1H), 1.26−1.12 (m, 12H), 0.98 (dddd, *J* = 12.6, 12.6, 11.4, 4.2 Hz, 1H), 0.89 (m, 1H); ^{13}C NMR (150 MHz, C_6D_6) δ 199.9, 135.96 (2C), 135.94 (2C), 134.31, 134.29,

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130.0, 129.9, 128.1 (2C), 128.0 (2C), 74.4, 72.7, 60.6, 50.1, 39.7, 31.5, 31.4, 27.1 (3C), 23.6, 19.4; HRMS (ESI) calcd for $C_{25}H_{34}O_3SiNa$ $[(M + Na)^+]$ 433.2169, found 433.2169.

Amide (±)-59. To a solution of thioester (±)-**21** (41.9 mg, 0.0786 mmol) in toluene (1 mL) were added piperidine (0.023 mL, 0.23 mmol) and $AgOCOCF_3$ (19.1 mg, 0.0865 mmol), and the resultant mixture was stirred at 60 °C for 20 min. After being cooled to room temperature, the resultant mixture was diluted with CH_2Cl_2 and 10% NH_4OH and stirred vigorously for 10 min. Insoluble materials were filtered off, and the filtrate was extracted with CH_2Cl_2. The combined organic layers were dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (30% EtOAc/hexanes) gave amide (±)-**59** (38.5 mg, 99%) as a colorless oil: IR (film) 2933, 2856, 1639, 1428, 1195, 1111, 703, 504 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.65–7.62 (m, 4H), 7.41–7.34 (m, 6H), 3.77–3.67 (m, 3H), 3.56–3.47 (m, 2H), 3.44–3.37 (m, 2H), 3.29 (m, 1H), 2.58 (dd, J = 14.4, 6.0 Hz, 1H), 2.31 (dd, J = 14.4, 6.6 Hz, 1H), 1.80–1.70 (m, 3H), 1.68–1.62 (m, 2H), 1.60–1.44 (m, 7H), 1.19–1.10 (m, 2H), 1.02 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 169.2, 135.5 (4C), 134.0, 133.9, 129.5, 128.3, 127.58 (2C), 127.57 (2C), 75.4, 74.8, 60.5, 47.1, 42.6, 40.2, 39.5, 31.7, 31.5, 26.8 (3C), 26.5, 25.6, 24.5, 23.5, 19.2; HRMS (ESI) calcd for $C_{30}H_{44}NO_3Si$ $[(M + H)^+]$ 494.3085, found 494.3092.

Enone (±)-60. To a solution of thioester (±)-**21** (43.3 mg, 0.0813 mmol), $Pd_2(dba)_3$ (3.7 mg, 0.0040 mmol), and CuDPP (45.6 mg, 0.162 mmol) in degassed THF (1.0 mL) were added a solution of $(EtO)_3P$ (0.006 mL, 0.03 mmol) in THF (0.1 mL) and tri(*n*-butyl)vinylstannane (0.030 mL, 0.10 mmol), and the resultant mixture was stirred at room temperature overnight (21 h). The resultant mixture was diluted with CH_2Cl_2 and treated with Celite. The resultant suspension was stirred at room temperature for a while, and then filtered through a pad of Celite. The filtrate was concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (3 to 5 to 10% EtOAc/hexanes) gave enone (±)-**60** (28.2 mg, 79%) as a yellow oil, along with recovered starting material (8.1 mg, 19%). Data for (±)-**60**: IR (film) 2931, 2856, 1685, 1427, 1111, 702, 737, 504 cm^{-1}; ^1H NMR (600 MHz, C_6D_6) δ 7.81–7.76 (m, 4H), 7.28–7.21 (m, 6H), 6.12 (dd, J = 17.5, 10.7 Hz, 1H), 5.86 (dd, J = 17.5, 1.0 Hz, 1H), 5.15 (dd, J = 10.7, 1.0 Hz, 1H), 3.87 (m, 1H), 3.79 (m, 1H), 3.75 (m, 1H), 3.41 (m, 1H), 2.62 (dd, J = 15.5, 6.5 Hz, 1H), 2.25 (dd, J = 15.5, 5.8 Hz, 1H), 1.77 (m, 1H), 1.69 (m, 1H), 1.50 (m, 1H), 1.43 (m, 1H), 1.28–1.19 (m, 2H), 1.18 (s, 9H), 1.06–0.94 (m, 2H); ^{13}C NMR (150 MHz, C_6D_6) δ 197.7, 137.3, 135.99 (2C), 135.96 (2C), 134.5, 134.4, 129.89 (2C), 129.86 (2C), 128.3 (2C), 127.2, 74.6, 74.4, 60.9, 46.7, 40.0, 31.8 (2C), 27.1 (3C), 23.7, 19.5; HRMS (ESI) calcd for $C_{27}H_{36}O_3SiNa$ $[(M + Na)^+]$ 459.2326, found 459.2337.

Phenyl Ketone (±)-61. To a solution of thioester (±)-**21** (66.9 mg, 0.126 mmol), $PhB(OH)_2$ (23.0 mg, 0.189 mmol), $Pd_2(dba)_3$ (5.8 mg, 0.0063 mmol), and CuTC (35.9 mg, 0.188 mmol) in degassed THF (1.7 mL) was added a solution of $(EtO)_3P$ (0.0086 mL, 0.050 mmol) in degassed THF (0.1 mL), and the resultant mixture was stirred at room temperature for 2 h 50 min. The resultant mixture was diluted with Et_2O, washed with saturated aqueous $NaHCO_3$ solution and brine, dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Flash chromatography on silica gel (5% EtOAc/hexanes) followed by preparative HPLC ($CHCl_3$) gave phenyl ketone (±)-**61** (34.7 mg, 57%) as a colorless oil: IR (film) 2931, 2856, 1682, 1427, 1111, 702, 502 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.93–7.91 (m, 2H), 7.63–7.59 (m, 4H), 7.51 (m, 1H), 7.41–7.31 (m, 8H), 3.89 (dddd, J = 12.6, 7.2, 6.0, 1.8 Hz, 1H), 3.70 (ddd, J = 10.2, 7.8, 6.0 Hz, 1H), 3.64 (ddd, J = 10.2, 6.6, 6.6 Hz, 1H), 3.53 (dddd, J = 12.6, 7.8, 4.8, 1.8 Hz, 1H), 3.19 (dd, J = 16.2, 6.0 Hz, 1H), 2.92 (dd, J = 16.2, 7.2 Hz, 1H), 1.80 (m, 1H), 1.74 (m, 1H), 1.71–1.61 (m, 2H), 1.59–1.51 (m, 2H), 1.24–1.14 (m, 2H), 1.00 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 198.7, 137.4, 135.52 (2C), 135.51 (2C), 134.1, 134.0, 132.9, 129.4 (2C), 128.4 (2C), 128.2 (2C), 127.54 (2C), 127.53 (2C), 74.7, 74.5, 60.2, 45.5, 39.4, 31.7, 31.5, 26.8 (3C), 23.5, 19.2; HRMS (ESI) calcd for $C_{31}H_{38}O_3SiNa$ $[(M + Na)^+]$ 509.2482, found 509.2487.

Ynone (±)-62. To a solution of thioester (±)-**21** (59.1 mg, 0.111 mmol), $Pd_2(dba)_3{\cdot}CHCl_3$ (5.7 mg, 0.0055 mmol), $(2\text{-furyl})_3P$ (10.3 mg, 0.0444 mmol), and CuI (35.9 mg, 0.188 mmol) in degassed DMF (1.0 mL) were added ethynylbenzene (0.025 mL, 0.23 mmol) and Et_3N (0.2 mL). The resultant mixture was stirred at 50 °C for 17 h. After being cooled to room temperature, the reaction mixture was diluted with Et_2O and H_2O and treated with Celite. The resultant suspension was stirred at room temperature for a while. Insoluble materials were filtered off, and the filtrate was washed with brine, dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Flash chromatography on silica gel (3 to 5 to 50% EtOAc/hexanes) followed by preparative HPLC ($CHCl_3$) gave ynone (±)-**62** (42.9 mg, 76%) as a yellow oil: IR (film) 2931, 2856, 2204, 1670, 1427, 1110, 1085, 757, 703, 504 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.64–7.61 (m, 4H), 7.52–7.49 (m, 2H), 7.43–7.31 (m, 9H), 3.93 (dddd, J = 13.2, 7.2, 6.0, 2.4 Hz, 1H), 3.78 (ddd, J = 10.2, 7.8, 6.0 Hz, 1H), 3.69 (ddd, J = 10.2, 6.0, 5.4 Hz, 1H), 3.56 (dddd, J = 12.6, 7.8, 4.8, 2.4 Hz, 1H), 2.86 (dd, J = 15.6, 7.2 Hz, 1H), 2.67 (dd, J = 15.6, 6.0 Hz, 1H), 1.82 (m, 1H), 1.75–1.61 (m, 3H), 1.60–1.51 (m, 2H), 1.27–1.14 (m, 2H), 1.00 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 185.7, 135.52 (2C), 135.49 (2C), 134.0, 133.9, 133.0 (2C), 130.6, 129.5 (2C), 128.6 (2C), 127.56 (2C), 127.55 (2C), 120.0, 90.8, 88.0, 74.8, 73.9, 60.2, 52.1, 39.2, 31.30, 31.27, 26.8 (3C), 23.5, 19.2; HRMS (ESI) calcd for $C_{33}H_{38}O_3SiNa$ $[(M + Na)^+]$ 533.2482, found 533.2478.

Carboxylic Acid (±)-63. To a solution of imide (±)-**29c** (42.3 mg, 0.085 mmol) in THF (1.4 mL) at 0 °C were added a solution of $LiOH{\cdot}H_2O$ (7.2 mg, 0.17 mmol) in H_2O (0.5 mL) and H_2O_2 (30% aqueous solution, 38 μL, 0.34 mmol). The resultant solution was stirred at room temperature for 5 h before it was quenched with saturated aqueous Na_2SO_3 solution. The mixture was diluted with H_2O and washed with CH_2Cl_2. The aqueous layer was acidified with 1 M aqueous HCl solution and extracted with EtOAc. The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (20% EtOAc/hexanes) gave carboxylic acid (±)-**63** (32.3 mg, 89%) as colorless oil: IR (film) 3647, 2931, 1715, 1541, 1111, 702 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.65–7.61 (m, 4H), 7.43–7.34 (m, 6H), 3.77 (dddd, J = 8.2, 5.5, 5.2, 5.1 Hz, 1H), 3.73–3.62 (m, 3H), 2.54–2.46 (m, 2H), 1.84 (m, 1H), 1.77–1.66 (m, 2H), 1.64–1.47 (m, 3H), 1.31–1.18 (m, 3H), 1.03 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 173.7, 135.5 (4C), 133.9, 133.8, 129.6 (2C), 127.6 (4C), 75.4, 73.9, 60.0, 41.0, 39.1, 31.1, 30.9, 26.9 (3C), 23.1, 19.2; HRMS (ESI) calcd for $C_{25}H_{34}O_4SiNa$ $[(M + Na)^+]$ 449.2119, found 449.2117.

Ester (±)-64. To a solution of imide (±)-**29c** (47.2 mg, 0.095 mmol) in CH_2Cl_2 (1.0 mL) at −25 °C was treated with a cold (0 °C) solution of NaOMe (0.5 M solution in MeOH, 0.20 mL, 0.10 mmol) over 15 min. The resultant solution was stirred at −25 °C for 15 min before it was quenched with saturated aqueous NH_4Cl solution. The resultant mixture was extracted with EtOAc. The organic layer was washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (5% EtOAc/hexanes) gave methyl ester (±)-**64** (40.0 mg, 96%) as colorless clear oil: IR (film) 2931, 1742, 1428, 1111, 703 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.66–7.62 (m, 4H), 7.41–7.34 (m, 6H), 3.75 (ddd, J = 13.7, 7.6, 6.2 Hz, 1H), 3.74–3.67 (m, 2H), 3.58 (s, 3H), 3.51 (dddd, J = 12.8, 12.7, 4.5, 1.7 Hz, 1H), 2.48 (dd, J = 15.0, 7.2 Hz, 1H), 2.35 (dd, J = 15.0, 6.6 Hz, 1H), 1.82–1.48 (m, 6H), 1.26–1.12 (m, 2H), 1.02 (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 171.8, 135.5 (4C), 134.1, 134.0, 129.5 (2C), 127.6 (4C), 74.7, 74.3, 60.4, 51.5, 41.6, 39.3, 31.3, 31.2, 26.8 (3C), 23.4, 19.2; HRMS (ESI) calcd for $C_{26}H_{36}O_4SiNa$ $[(M + Na)^+]$ 463.2281, found 463.2276.

Aldehyde (±)-58 (from (±)-29c). To a solution of imide (±)-**29c** (43.6 mg, 0.088 mmol) in CH_2Cl_2 (1.0 mL) at −78 °C was added DIBALH (1.03 M solution in *n*-hexane, 0.094 mL, 0.097 mmol), and the resultant solution was stirred at −78 °C for 3 h before it was quenched with MeOH. The reaction mixture was diluted with saturated aqueous potassium sodium tartrate solution and EtOAc, and the resultant biphasic mixture was vigorously stirred at room temperature until the layers become clear. The organic layer was separated, and the aqueous layer was extracted with EtOAc. The

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combined organic layers were washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (5 to 10% EtOAc/hexanes) gave aldehyde (±)-**58** (28.8 mg, 80%) as a colorless oil. The spectroscopic data of this material were matched those reported above.

Carboxylic Acid (±)-63 (from (±)-29g). To a solution of amide (±)-**29g** (34.4 mg, 0.0683 mmol) in THF (1.0 mL) at 0 °C were added a solution of $LiOH·H_2O$ (5.7 mg, 0.14 mmol) in H_2O (0.3 mL) and 30% aqueous H_2O_2 solution (31 μL, 0.27 mmol). The resultant mixture was stirred at room temperature for 23 h. After being cooled to 0 °C, the mixture were treated with a solution of $LiOH·H_2O$ (5.7 mg, 0.14 mmol) in H_2O (0.3 mL) and 30% aqueous H_2O_2 solution (31 μL, 0.27 mmol). The resultant mixture was stirred at room temperature for 3.5 h before it was quenched with saturated aqueous Na_2SO_3 solution. The resultant mixture was diluted with H_2O and washed with CH_2Cl_2. The aqueous layer was acidified with 1 M aqueous HCl solution and extracted with EtOAc. The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (10% EtOAc/benzene) gave carboxylic acid (±)-**63** (27.8 mg, 96%) as a colorless oil. The spectroscopic data of this material matched those reported above.

Ester (±)-64 (from (±)-29g). To a solution of amide (±)-**29g** (44.2 mg, 0.088 mmol) in CH_2Cl_2 (1.0 mL) at −25 °C was added a cold (0 °C) solution of NaOMe (0.5 M solution in MeOH, 0.20 mL, 0.10 mmol). The resultant solution was stirred at 0 °C for 17 h before it was quenched with saturated aqueous NH_4Cl solution. The resultant mixture was extracted with EtOAc. The organic layer was washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (10% EtOAc/hexanes) gave methyl ester (±)-**64** (36.0 mg, 93%) as a colorless clear oil. The spectroscopic data of this material matched those reported above.

Aldehyde (±)-58 (from (±)-29g). To a solution of amide (±)-**29g** (53.9 mg, 0.11 mmol) in toluene/CH_2Cl_2 (1:1, v/v, 1.0 mL) at 0 °C was added DIBALH (1.03 M solution in *n*-hexane, 0.12 mL, 0.13 mmol), and the resultant solution was stirred at 0 °C for 10 min before it was quenched with MeOH. The reaction mixture was diluted with saturated aqueous potassium sodium tartrate solution and EtOAc, and the resultant biphasic mixture was vigorously stirred at room temperature until the layers became clear. The organic layer was separated, and the aqueous layer was extracted with EtOAc. The combined organic layers were washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (10% EtOAc/hexanes) gave pyrrole carbinol (±)-**65** (53.4 mg, 99%) as a 1:1 mixture of diastereomers and as a colorless oil: IR (film) 3420, 3070, 2931, 2857, 1716, 1428, 1392, 1284, 1110, 702 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 7.66−7.62 (m, 4H), 7.42−7.34 (m, 6H), 5.75 (m, 1H), 5.71 (s, 2H), 3.78−3.68 (m, 2H), 3.53−3.48 (m, 2H), 3.30 (m, 1H), 2.28−2.24 (m, 7H), 2.18 (m, 1H), 1.91 (ddd, *J* = 14.5, 5.9, 2.1 Hz, 1H), 1.84−1.75 (m, 2H), 1.66 (m, 1H), 1.45 (m, 1H), 1.29−1.13 (m, 3H), 1.03 ppm (s, 9H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 135.5 (4C), 133.9, 133.8, 129.6 (2C), 127.9 (2C), 127.6 (4C), 106.7, 106.6, 78.8, 75.6 (1/2C), 74.9 (1/2C), 74.7 (1/2C), 74.5 (1/2C), 60.5, 42.7, 39.4 (1/2C), 39.3 (1/2C), 31.7 (1/2C), 31.5 (1/2C), 31.1 (1/2C), 26.9 (3C), 23.5 (1/2C), 23.2, 19.2, 13.6, 13.5 ppm; HRMS (ESI) calcd for $C_{31}H_{43}NNaO_3Si$ [$(M + Na)^+$] 528.2904, found 528.2892.

To a solution of pyrrole carbinol (±)-**65** (33.6 mg, 0.067 mmol) in MeOH (1.0 mL) was added $CaCO_3$ (1.0 mg, 10 μmol), and the resultant solution was stirred at 60 °C for 28.5 h. The reaction mixture was cooled to room temperature, diluted with EtOAc, washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash chromatography on silica gel (benzene) gave aldehyde (±)-**58** (20.8 mg, 74%) as a colorless oil. The spectroscopic data of this material matched those reported above.

■ ASSOCIATED CONTENT

Supporting Information

Stereochemical assignment of the cyclization products and copies of ^1H and ^{13}C NMR spectra for all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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