Determination of the Stereochemistry of the Tetrahydropyran Sesquineolignans Morinols A and B

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The 7′,8′-stereochemistry of the tetrahydropyran sesquineolignans morinols A and B was determined as *threo* via synthetic studies and by comparison of NMR data of 7′,8′-*threo*-morinol and 7′,8′-*erythro*-morinol. This study also confirmed that the biosynthetic process produces enantiomeric mixtures of morinols A and B. This was ascertained by comparing the specific rotations of synthesized morinols A and B with those of naturally occurring morinols A and B.

The unique tetrahydropyran sesquineolignans morinols A and B have been isolated from the Chinese traditional medicinal plant *Morina chinensis* as a racemic mixture (Figure 1).[1,2] The inhibition of cytokines by morinols A and B and the stronger activity of morinol B than morinol A have also been reported.[2] This activity of lignans on cytokines is rare, even though many biological activities of naturally occurring lignans are known.[3,4] The biosynthesis of enantiomeric lignans has also been reported.[5] Therefore, the synthesis of optically pure lignans is important to determine their precise biological activity. The relationship between lignan structure and biological activity is complex because of numerous combinations of phenylpropanoid units and oxidation patterns. The synthesis and characterization of lignans[6] are continuing to clarify which structural features of lignans determine biological activity. Morinols A and B were obtained as a racemic mixture from natural sources and used for biological research. The relative configuration of the 7′ and 8′ stereocenters are undefined. These facts persuaded us to synthesize optically pure morinols A and B to define their absolute configuration. The success of the synthetic study of morinols A and B would also contribute to research about the structure/activity relationship of tetrahydropyran sesquineolignans. Furthermore, the precise biological activity could be determined and new factors responsible for the biological activity of the novel structure would be clarified. A chiral secondary benzyl alcohol adjacent to another chiral carbon is common in lignan structures.[4] These functionalities occur in both *erythro* and *threo* forms. However, the determination of the relative configuration is problematic. Thus syntheses of 7′,8′-*threo*-morinols A and B and 7′,8′-*erythro*-morinols A and B were performed to determine their stereochemistries.

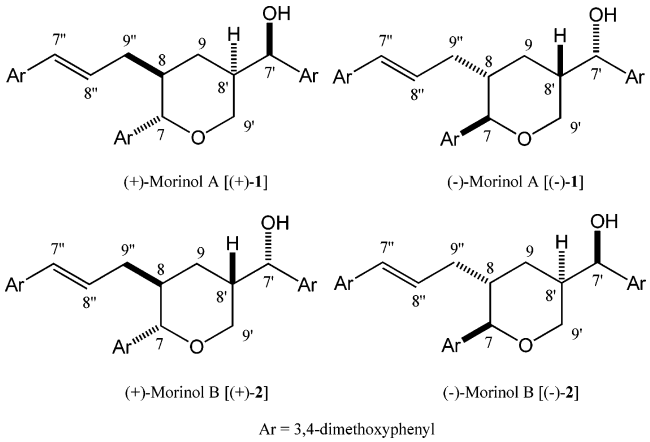

Figure 1. Morinol A and morinol B were isolated as enantiomeric mixtures.[1,2]

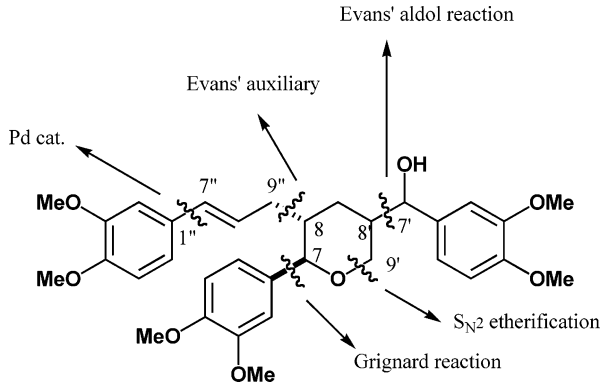

Figure 2. Synthetic plan of morinols A and B.

Results and Discussion

The synthetic plan is shown in Figure 2. The tetrahydropyran ring was obtained by S_N2 etherification between the benzyl alcohol and primary mesylate. The C-7 chiral carbon was constructed by a Grignard reaction. The C-8 chiral carbon was asymmetrically introduced by allylation using Evans' chiral auxiliary. The selection of morinol A (8,8′-*cis*) type or morinol B (8,8′-*trans*) type was achieved by *S* or *R* Evans' auxiliary before this allylation. The stereocontrol of *erythro* or *threo* between C-7′ and C-8′ was achieved by an Evans' *syn*[7] or *anti*[8] selective aldol condensation, respectively. This synthetic strategy could be readily applied to morinol A and B derivatives. Thus, the introduction of a 3″,4″-dimethoxyphenyl group at C-7″ using a Pd catalyst was planned.

This article shows the determination of the stereochemistry of both morinols A and B by their first *in vitro* synthesis. A new example of lignan biosynthesis as an enantiomeric mixture is also confirmed by comparison of the specific rotations of synthesized morinols A and B with those of previously isolated morinols A and B.[1,2]

The plan for the construction of the tetrahydropyran structure **17**, which has the 7′,8′-*threo*-morinol B configuration, required the synthesis of substrate **15** (Scheme 1). The chiral carbons of **15** were introduced by Evans' *anti*-aldol[8] condensation, allylation by employing Evans' chiral auxiliary, and a Grignard reaction. The Evans' *anti*-aldol condensation between **3** and 3,4-dimethoxybenzaldehyde employing Et_3N, chlorotrimethylsilane, and $MgCl_2$ gave **4** (93% yield), which was transformed to silyl ether **5** by using

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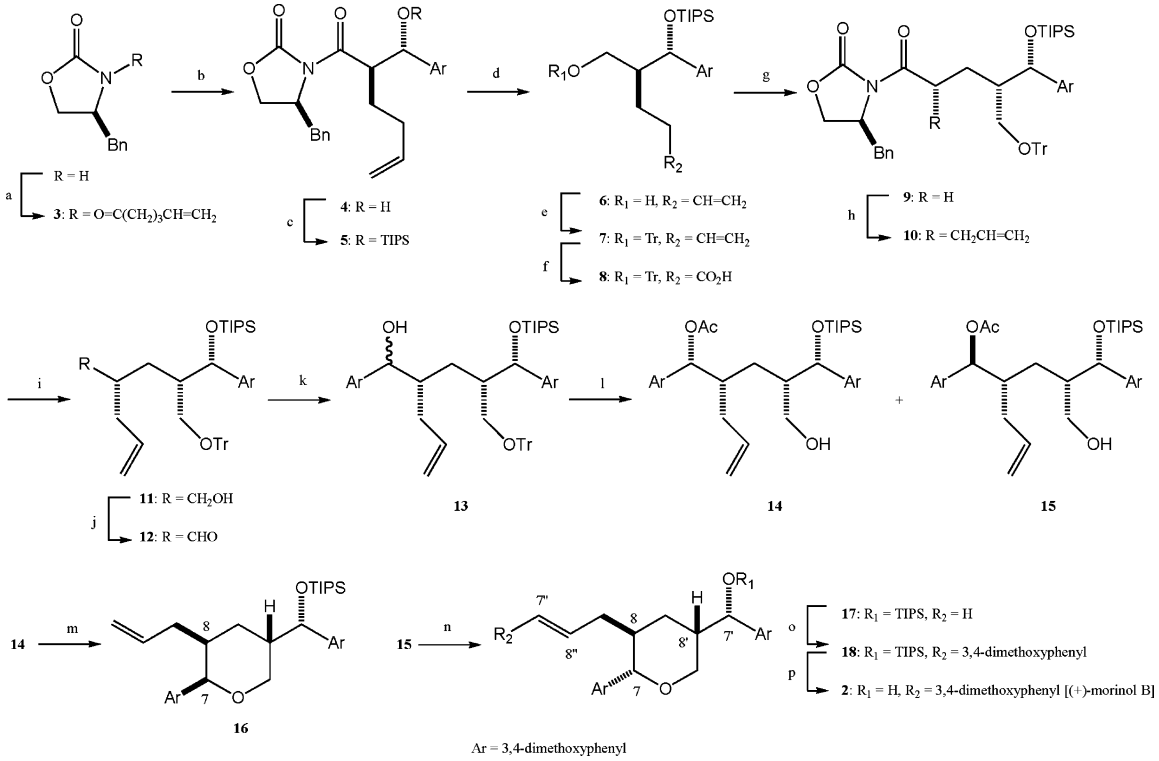
Scheme 1. Synthesis of Morinol B[a]

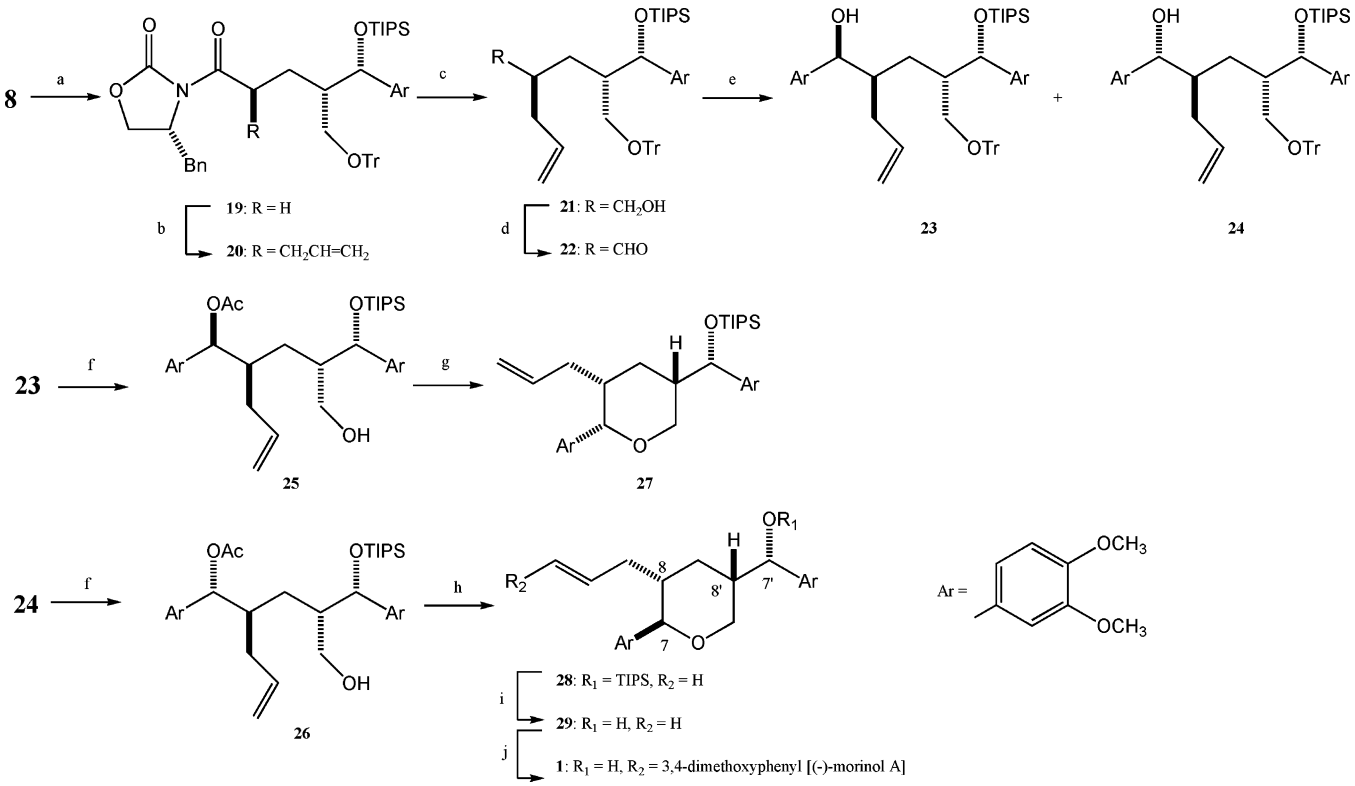


[a] (a) 5-hexenoic acid, Et_3N, PivCl, THF, 0 °C, 1 h, then lithium salt of (*S*)-4-benzyl-2-oxazolidinone, THF, from −70 to 0 °C, 1 h (80% yield); (b) (1) Et_3N, TMSCl, $MgCl_2$, 3,4-dimethoxybenzaldehyde, EtOAc, rt, 16 h; (2) TFA, MeOH, rt, 30 min (93% yield); (c) TIPSOTf, 2,6-lutidine, CH_2Cl_2, rt, 1 h (91% yield); (d) $LiBH_4$, MeOH, THF, rt, 6 h (60% yield); (e) TrCl, DMAP, C_5H_5N, 60 °C, 16 h (81% yield); (f) (1) OsO_4, NMO, aq acetone, *tert*-BuOH, rt, 16 h; (2) $NaIO_4$, MeOH, rt, 3 h; (3) 2-methyl-2-butene, $NaH_2PO_4 \cdot 2H_2O$, $NaClO_2$, aq *tert*-BuOH, rt, 1 h (86% yield); (g) Et_3N, PivCl, 0 °C, 1 h, then lithium salt of (*S*)-4-benzyl-2-oxazolidinone, from −70 to 0 °C, 1 h (88% yield); (h) KHMDS, allyl bromide, THF, from −70 °C to rt, 16 h (50% yield); (i) $LiBH_4$, MeOH, THF, rt, 1 h (89% yield); (j) PCC, MS 4Å, CH_2Cl_2, rt, 16 h (76% yield); (k) 3,4-$(MeO)_2$PhMgBr, THF, rt, 1 h (93% yield); (l) (1) Ac_2O, C_5H_5N, rt, 16 h; (2) HCO_2H, ether, −5 °C, 10 min (**14**: 35% yield, **15**: 38% yield); (m) (1) MsCl, Et_3N, CH_2Cl_2, 0 °C, 30 min; (2) K_2CO_3, MeOH, rt, 16 h; (3) NaH, DMF, rt, 16 h (70% yield); (n) (1) MsCl, Et_3N, CH_2Cl_2, 0 °C, 30 min; (2) K_2CO_3, MeOH, rt, 16 h (56% yield); (o) 1-Br-3,4-$(MeO)_2C_6H_3$, Et_3N, $PdCl_2(PPh_3)_2$, DMF, 90 °C, 6 h (33% yield, recovered **17**, 58%); (p) *n*-Bu_4NF, THF, rt, 3 h (100% yield).

triisopropylsilyl triflate and 2,6-lutidine. The trityl ether **7** was obtained by reductive ($LiBH_4$) removal of the chiral auxiliary of **5** (60% yield) followed by treatment with trityl chloride in pyridine (81% yield). To introduce the Evans' chiral auxiliary, olefin **7** was converted to carboxylic acid **8** by OsO_4 oxidation, then $NaIO_4$ oxidation and then $NaClO_2$ oxidation (86% yield, three steps). Attachment of *S*-Evans' chiral auxiliary to carboxylic acid **8** was achieved by coupling of the pivaloic anhydride of carboxylic acid **8** with the lithium salt of (*S*)-4-benzyl-2-oxazolidinone in 88% yield. The stereoselective allylation to **9** was accomplished by employing potassium bis(trimethylsilylamide) and allyl bromide to give **10** (50% yield) as a single isomer. Formation of the other stereoisomer was not observed. Since the α-allylation to the lactone, which was obtained from **8** by detritylation, gave the diallyl compound, allylation using a chiral auxiliary was adopted. The allylation using sodium bis(trimethylsilylamide) did not give the allyl product. Reductive ($LiBH_4$) removal of the chiral auxiliary of **10** (89% yield) followed by pyridinium chlorochromate oxidation (76% yield) gave aldehyde **12**. Treatment of aldehyde **12** with 3,4-dimethoxyphenylmagnesium bromide gave benzyl alcohol **13** as a 1:1 mixture of diastereomers in 93% yield. Detritylation of **13** using formic acid in ether was accompanied by desilylation, giving the corresponding triol. However, detritylation of acetate of **13** gave separable alcohols **14** (35% yield) and **15** (38% yield). At this stage, the cyclization of the substrate to tetrahydropyran was obtained. The configurations of **14** and **15** were not determined at this stage. After conversion of **15** to the corresponding mesylate by using $MeSO_2Cl$ and Et_3N, the resulting crude mesylate was exposed to K_2CO_3 in MeOH, giving tetrahydropyran **17** in 56% yield.

The next key step involved formation of the cinnamyl compound by the coupling of aryl halide with olefin employing a Pd catalyst. The Mizorogi−Heck reaction is known to couple an aryl halide with a conjugate olefin or enol using Pd catalysis. However, olefin **17** is not a conjugate olefin. This case is not typical of coupling reactions using Pd catalysts. Cesati et al. have reported Pd catalytic coupling reactions between aryl bromide and ethylene using $PdCl_2(PPh_3)_2$.[9] The $PdCl_2(PPh_3)_2$-catalyzed coupling reaction between 1-bromo-3,4-dimethoxybenzene and olefin **17** was carried out in DMF at 90 °C, giving *trans*-olefin **18** in 33% yield. A 58% portion of olefin **17** was recovered. Only the *trans*-olefin showing a coupling constant of 16.1 Hz for H-7″ and H-8″ was obtained. The formation of *cis*-olefin was not observed. The coupling constant of H-7 of **18** (9.3 Hz, diaxial) became clear at this stage, showing the *trans*-configuration of the C-7−C-8 bond. To compare the coupling constant of H-7, the 7,8-*cis*-compound **16** was prepared from Grignard product **14** by mesylation and deacetylation followed by treatment with sodium hydride in DMF. The H-7 coupling constant of the 7,8-*cis*-compound **16** was 2.0 Hz (axial−equatorial). Finally, desilylation of **18** by treatment with TBAF gave (+)-morinol B in quantitative yield. NMR data agreed with those in the literature.[1,2] (−)-Morinol B was also synthesized from (*R*)-**3** by almost the same synthetic method. In the step for introduction of a chiral auxiliary before allylation, (*R*)-Evans' chiral auxiliary was employed. These facts mean that the relative configuration of the C-7′−C-8′ bond of naturally occurring morinol B is *threo*. The specific rotations of synthesized (+)- and (−)-morinol B were +69 and −69, respectively. On the other hand, specific rotation of isolated morinol B was reported as −3.92.[1,2] This shows that morinol B was biosynthesized as an enantiomeric mixture. The enantiomeric excess of synthesized (+)- and (−)-morinol B was established as more than 99% each by HPLC analysis using a chiral column.

Scheme 2. Synthesis of Morinol A[a]



[a] (a) Et_3N, PivCl, 0 °C 1 h, then lithium salt of (*R*)-4-benzyl-2-oxazolidinone, from −70 to 0 °C, 1 h (83% yield); (b) KHMDS, allyl bromide, THF, from −70 °C to rt, 16 h (59% yield); (c) $LiBH_4$, MeOH, THF, rt, 1 h (90% yield); (d) PCC, MS 4Å, CH_2Cl_2, rt, 16 h (100% yield); (e) 3,4-$(MeO)_2$PhMgBr, THF, rt, 1 h (**23**: 28% yield, **24**: 26% yield); (f) (1) Ac_2O, C_5H_5N, rt, 16 h; (2) HCO_2H, ether, −5 °C, 10 min (**25**: 58% yield, **26**: 59% yield); (g) (1) MsCl, Et_3N, Ch_2Cl_2, 0 °C, 30 min; (2) K_2CO_3, MeOH, rt, 16 h; (3) NaH, DMF, rt, 16 h (95% yield); (h) (1) MsCl, Et_3N, CH_2Cl_2, 0 °C, 30 min; (2) K_2CO_3, MeOH, rt, 16 h (54% yield); (i) *n*-Bu_4NF, THF, rt, 3 h (94% yield); (j) 1-Br-3,4-$(MeO)_2C_6H_3$, Et_3N, $PdCl_2(PPh_3)_2$, DMF, 90 °C, 6 h (31% yield, recovered **29**, 67%).

To synthesize 7′,8′-*threo*-morinol A, carboxylic acid **8** was selected as a starting material (Scheme 2). After attachment of *R*-Evans' chiral auxiliary, the resulting compound **19** was converted to Grignard products **23** and **24**. Compound **24** was transformed to allyl tetrahydropyran **29** to examine the olefin coupling reaction using an olefin without a silyl group. The coupling reaction of olefin **29** with 1-bromo-3,4-dimethoxybenzene using $PdCl_2(PPh_3)_2$ gave (−)-morinol A (31% yield) and recovered olefin **29** (67%). NMR data agreed with those in the literature.[1,2] (+)-Morinol A was also synthesized by the same method. It was confirmed that the relative configuration of the C-7′−C-8′ bond of naturally occurring morinol A is also the *threo* form and morinol A is biosynthesized as an enantiomeric mixture. The specific rotations of synthesized (+)- and (−)-morinol A were +15 and −15, respectively. On the other hand, the specific rotation of isolated morinol B was reported as +0.98.[1,2] The HPLC analysis using a chiral column showed that the enantiomeric excess of synthesized (+)- and (−)-morinol A was more than 99% ee.

To ensure the stereochemistry of morinols A and B, (−)-7′,8′-*erythro*-morinols A (**31**) and B (**32**) were synthesized from Evans' *syn* aldol product **30** (Scheme 3). The ^{13}C NMR spectrum of (+)-7′,8′-*erythro*-morinol B (**32**) was different from that of (+)-7′,8′-*threo*-morinol B (**2**); however, the ^{13}C NMR spectrum of (−)-7′,8′-*erythro*-morinol A (**31**) was similar to that of (−)-7′,8′-*threo*-morinol A (**1**). A clear difference between the 7′,8′-*threo* and 7′,8′-*erythro* isomers was observed in the chemical shifts of H_2-9, H-7″, and H-8″. The H_2-9′ of the 7′,8′-*threo* isomers (morinol A: 3.42 and 4.38 ppm; morinol B: 3.74 and 4.50 ppm) resonates at lower field than that of the 7′,8′-*erythro* isomers (morinol A: 3.28 and 3.84−3.89 ppm, morinol B: 3.64 and 3.86−3.92 ppm). Both H-7″ and H-8″ of the 7′,8′-*threo* isomers (morinol A: H-7″, 6.09 ppm, H-8″, 5.71 ppm; morinol B: H-7″, 6.08 ppm, H-8″, 5.69 ppm) resonate at higher field than those of the 7′,8′-*erythro* isomers (morinol A: H-7″, 6.17 ppm, H-8″, 5.85 ppm; morinol B: H-7″, 6.19 ppm, H-8″, 5.87 ppm). The coupling constants of H-7′ of the 7′,8′-*threo* isomers (morinol A: 9.1 Hz; morinol B: 9.0 Hz) were larger than those of the 7′,8′-*erythro* isomers (morinol A: 7.3 Hz; morinol B: 8.5 Hz).

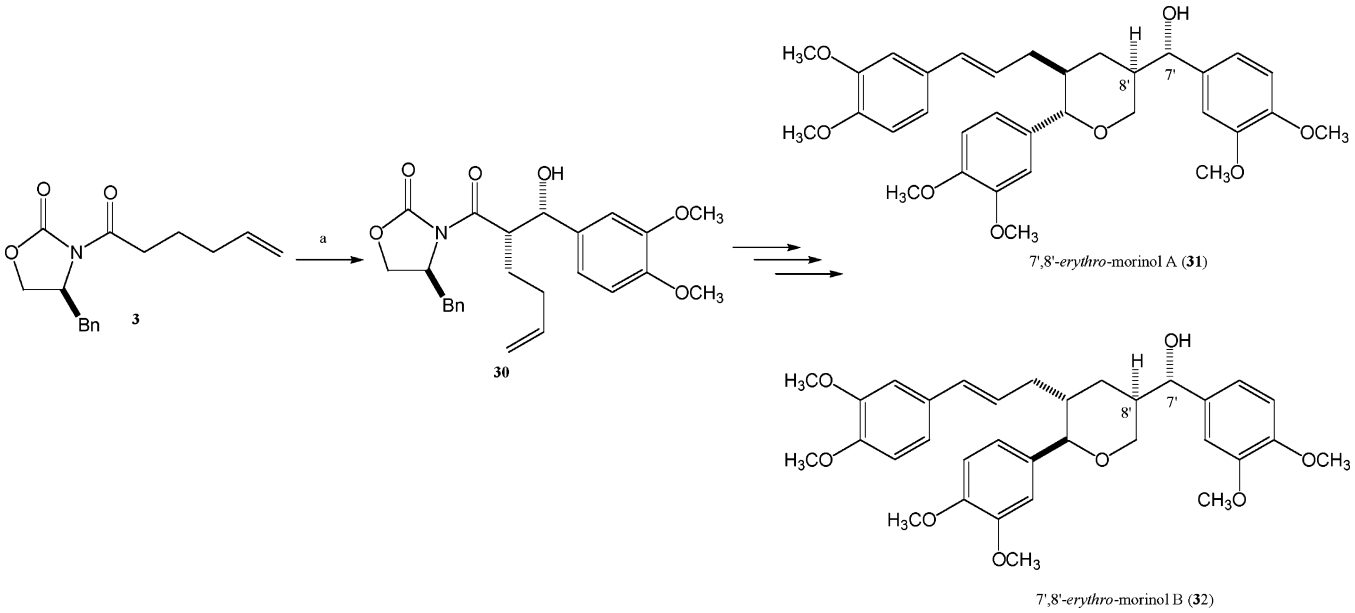
The stereochemistry of naturally occurring tetrahydropyran sesquineolignans morinols A and B was determined as 7′,8′-*threo* by enantioselective syntheses of (+)- and (−)-morinols A and B. The syntheses of the 7′,8′-*erythro* isomer permitted the comparison of chemical shifts. This research will contribute to biosynthetic and biological research on neolignans.

Experimental Section

General Experimental Procedures. Melting points were not corrected. Optical rotations were measured on a Horiba SEPA-200 instrument. NMR data were obtained using a JNM-EX400 spectrometer. EIMS data were measured with a JMS-MS700V spectrometer. The silica gel used was Wakogel C-300 (Wako, 200−300 mesh). HPLC analysis was performed with Shimadzu LC-6AD and SPD-6AV instruments. The numbering of compounds follows IUPAC nomenclatural rules.

(*S*)-4-Benzyl-3-(5-hexenoyl)-2-oxazolidinone (3). To a solution of 5-hexenoic acid (8.43 mL, 0.071 mol) in THF (200 mL) were added Et_3N (9.90 mL, 0.071 mol) and pivaloyl chloride (8.74 mL, 0.071 mol) at −70 °C, and then the mixture was stirred at 0 °C for 1 h. After cooling to −70 °C, a solution of the lithium salt of (*S*)-4-benzyl-2-oxazolidinone prepared from (*S*)-4-benzyl-2-oxazolidinone (12.5 g, 0.071 mol) and *n*-BuLi (1.6 M in THF, 44.4 mL, 0.071 mol) at −70 °C in THF (150 mL) was added, and then the reaction mixture was stirred at 0 °C for 1 h. After addition of a saturated aqueous NH_4Cl solution, the solution was separated, washed with brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:3) gave acyloxazolidinone **3** (15.6 g, 0.057 mol, 80%) as a colorless oil: $[\alpha]^{20}_D$ +69 (*c* 0.3, $CHCl_3$); ^1H NMR ($CDCl_3$) δ

Scheme 3. Syntheses of (−)-7′,8′-*erythro*-Morinol A and (+)-7′,8′-*erythro*-Morinol B[a]



[a] (a) 3,4-$(MeO)_2C_6H_3CHO$, Bu_2BOTf, Et_3N, CH_2Cl_2, from −65 to 0 °C, 1 h (100% yield).

1.77−1.85 (2H, m, H_2-3 of hexenoyl), 2.13−2.19 (2H, m, H_2-2 of hexenoyl), 2.77 (1H, dd, J = 13.5, 9.5 Hz, CH_{2a}Ph), 2.87−3.03 (2H, m, H_2-4 of hexenoyl), 3.29 (1H, dd, J = 13.5, 3.4 Hz, CH_{2b}PH), 4.14−4.22 (2H, m, H_2-5), 4.67 (1H, m, H-4), 4.99−5.08 (2H, m, H_2-6 of hexenoyl), 5.82 (1H, m, H-5), 7.20−7.21 (2H, m, ArH), 7.26−7.29 (1H, m, ArH), 7.30−7.35 (2H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 23.3, 33.0, 34.8, 37.9, 55.1, 66.1, 115.3, 127.3, 128.9, 129.4, 135.3, 137.8, 153.4, 173.1; *anal*. C 70.50%, H 7.02%, N 5.10%, calcd for $C_{16}H_{19}O_3N$, C 70.31%, H 7.01%, N 5.12%. (*R*)-**3**: $[\alpha]^{20}_D$ −69 (*c* 1.9, $CHCl_3$).

(*S*)-4-Benzyl-3-{(*R*)-2-[(*S*)-(hydroxy)(3,4-dimethoxyphenyl)methyl]-5-hexenoyl}-2-oxazolidinone (4). The reaction has previously been described.[10] Yield 93%, colorless oil: $[\alpha]^{20}_D$ −10 (*c* 2.2, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 1.52 (1H, m, H-3a of hexenoyl), 1.89 (1H, m, H-3b of hexenoyl), 2.02−2.07 (2H, m, H_2-4 of hexenoyl), 2.57 (1H, dd, J = 13.7, 9.8 Hz, CH_{2a}Ph), 3.12 (1H, d, J = 8.3 Hz, OH), 3.16 (1H, d, J = 13.7, 3.4 Hz, CH_{2b}Ph), 3.86 (3H, s, OCH_3), 3.90 (3H, s, OCH_3), 4.09−4.16 (2H, m, H_2-5), 4.48 (1H, m, 2-H of hexenoyl), 4.66 (1H, m, H-4), 4.78 (1H, dd, J = 8.3, 7.8 Hz, ArC*H*OH), 4.91−4.98 (2H, m, H_2-6 of hexenoyl), 5.71 (1H, m, H-5 of hexenoyl), 6.84 (1H, d, J = 8.3 Hz, ArH), 6.95 (1H, dd, J = 8.3, 2.0 Hz, ArH), 7.00 (1H, d, J = 2.0 Hz, ArH), 7.13−7.15 (2H, m, ArH), 7.25−7.32 (3H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 28.9, 31.5, 37.5, 48.6, 55.5, 55.8, 55.9, 65.8, 76.2, 109.3, 110.9, 115.2, 118.7, 127.3, 128.9, 129.4, 134.9, 135.2, 137.7, 148.7, 149.1, 153.7, 176.1; *anal*. C 68.13%, H 6.54%, N 2.99%, calcd for $C_{25}H_{29}O_6N$, C 68.32%, H 6.65%, N 3.19%. (*R*)-3-{(*S*)-2-[(*R*)]}-**4**: $[\alpha]^{20}_D$ +10 (*c* 1.1, $CHCl_3$).

(*S*)-4-Benzyl-3-{(*R*)-2-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]-5-hexenoyl}-2-oxazolidinone (5). The reaction has previously been described.[10] Yield 91%, colorless oil: $[\alpha]^{20}_D$ −45 (*c* 3.0, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.86−1.00 (21H, m, *i*-Pr), 1.24 (1H, m, H-3a of hexenoyl), 1.66 (1H, m, H-3b of hexenoyl), 1.86−1.90 (2H, m, H_2-4 of hexenoyl), 2.62 (1H, dd, J = 12.7, 11.2, CH_{2a}Ph), 3.58 (1H, dd, J = 12.7, 3.2 Hz, C_{2b}Ph-4), 3.88 (3H, s, OCH_3), 3.91 (3H, s, OCH_3), 4.08−4.16 (2H, m, H_2-5), 4.44 (1H, m, H-2 of hexenoyl), 4.64 (1H, m, H-4), 4.84−4.89 (2H, m, H_2-6 of hexenoyl), 4.98 (1H, d, J = 8.8 Hz, ArCHOSi), 5.61 (1H, m, H-5 of hexenoyl), 6.78 (1H, d, J = 7.8 Hz, ArH), 6.87 (1H, dd, J = 7.8, 1.6 Hz, ArH), 7.10 (1H, d, J = 1.6 Hz, ArH), 7.22−7.31 (3H, m, ArH), 7.34−7.38 (2H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.7, 17.9, 18.1, 28.6, 31.4, 38.4, 51.0, 55.79, 55.80, 56.2, 65.9, 77.8, 110.1, 110.5, 114.8, 120.2, 127.2, 129.0, 129.3, 135.2, 136.0, 138.0, 148.8, 148.9, 153.3, 175.3; *anal*. C 68.44%, H 8.58%, N 2.16%, calcd for $C_{34}H_{49}O_6NSi$, C 68.54%, H 8.29%, N 2.35%. (*R*)-{(*S*)-[(*R*)]}-**5**: $[\alpha]^{20}_D$ +45 (*c* 3.6, $CHCl_3$).

(*S*)-2-[(*S*)-(3,4-Dimethoxyphenyl)(triisopropylsilyloxy)methyl]-5-hexen-1-ol (6). The reaction has previously been described.[10] Yield 60%, colorless oil: $[\alpha]^{20}_D$ −48 (*c* 1.2, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.97−1.03 (21H, m, *i*-Pr), 1.40 (1H, m, H-3a), 1.47 (1H, m, H-3b), 1.76 (1H, m, H-2), 2.00 (1H, m, H-4a), 2.13 (1H, m, H-4b), 2.78 (1H, dd, J = 5.9, 4.9 Hz, OH), 3.57 (1H, ddd, J = 11.2, 5.9, 5.9 Hz, H-1a), 3.82 (1H, m, H-1b), 3.88 (6H, s, OCH_3), 4.85 (1H, d, J = 5.4 Hz, ArCHOSi), 4.91−4.99 (2H, m, H_2-6), 5.72 (1H, m, H-5), 6.75−6.83 (2H, m, ArH), 6.93 (1H, s, ArH); ^{13}C NMR ($CDCl_3$) δ 12.5, 18.0, 18.1, 27.0, 31.5, 47.8, 55.8, 63.0, 79.2, 109.9, 110.4, 114.7, 119.1, 136.1, 138.5, 148.3, 148.7; *anal*. C 67.75%, H 10.30%, calcd for $C_{24}H_{42}O_4Si$, C 68.20%, H 10.02%. (*R*)-[(*R*)]-**6**: $[\alpha]^{20}_D$ +48 (*c* 0.4, $CHCl_3$).

(5*S*,6*S*)-6-(3,4-Dimethoxyphenyl)-6-(triisopropylsilyloxy)-5-trityloxymethyl-1-hexene (7). A mixture of alcohol **6** (15.2 g, 0.036 mol) and trityl chloride (10.0 g, 0.036 mol), and DMAP (0.1 g, 0.00082 mol) in pyridine (50 mL) was stirred at 60 °C for 16 h. After addition of H_2O and EtOAc, the organic solution was separated, washed with a saturated aqueous $CuSO_4$ solution, a saturated aqueous $NaHCO_3$ solution, and brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:9) gave trityl ether **7** (19.0 g, 0.029 mol, 81%) as colorless crystals, mp 113−114 °C (*i*-Pr_2O): $[\alpha]^{20}_D$ −47 (*c* 1.2, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.69 (1H, m, H-4a), 1.00−1.06 (21H, m, *i*-Pr), 1.70 (1H, m, H-4b), 1.81−2.04 (2H, m, H_2-3), 2.30 (1H, m, H-5), 2.66 (1H, dd, J = 9.5, 9.5 Hz, $TrOCH_{2a}$), 3.21 (1H, dd, J = 9.5, 5.1 Hz, $TrOCH_{2b}$), 3.71 (3H, s, OCH_3), 3.81 (3H, s, OCH_3), 4.88−4.92 (2H, m, H_2-1), 5.30 (1H, d, J = 3.9 Hz, ArCHOSi), 5.70 (1H, m, H-2), 6.53 (2H, s, ArH), 6.85 (1H, s, ArH), 7.21−7.30 (9H, m, ArH), 7.40−7.47 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.4, 18.06, 18.13, 24.4, 31.8, 46.4, 55.7, 63.8, 73.8, 86.7, 109.8, 110.4, 114.4, 119.3, 126.9, 127.7, 128.7, 134.5, 139.0, 144.3, 147.6, 148.0; *anal*. C 77.49%, H 8.85%, calcd for $C_{43}H_{56}O_4Si$, C 77.67%, H 8.49%. (5*R*,6*R*)-**7**: $[\alpha]^{20}_D$ +47 (*c* 1.1, $CHCl_3$).

(4*S*,5*S*)-5-(3,4-Dimethoxyphenyl)-5-(triisopropylsilyloxy)-4-(trityloxymethyl)pentanoic Acid (8). A solution of olefin **7** (19.0 g, 0.029 mol) and 4-methylmorpholine *N*-oxide (3.95 g, 0.034 mol) in acetone (250 mL), *t*-BuOH (50 mL), and H_2O (25 mL) was stirred at room temperature for 16 h under N_2 gas. After addition of a saturated aqueous $Na_2S_2O_3$ solution, the mixture was concentrated. The residue was dissolved in H_2O and EtOAc. The organic solution was separated, washed with brine, and dried (Na_2SO_4). Concentration gave a crude glycol. A mixture of the crude glycol and $NaIO_4$ (7.22 g, 0.034 mol) in MeOH (150 mL) was stirred at room temperature for 3 h. After concentration, the residue was dissolved in H_2O and EtOAc. The organic solution was separated, washed with brine, and dried (Na_2SO_4). Concentration gave a crude aldehyde. To a solution of the crude aldehyde, 2-methyl-2-butene (13.1 mL, 0.12 mol), and $NaH_2PO_4 \cdot 2H_2O$ (4.37 g, 0.028 mol) in *t*-BuOH (200 mL) and H_2O (50 mL) was added $NaClO_2$ (80%, 11.0 g, 0.097 mol). The solution was stirred at room temperature for 1 h, and then $CHCl_3$ was added. After acidification with 1 M aqueous HCl solution, the organic solution was separated, washed with brine, and dried (Na_2SO_4). Concentration followed by silica

gel column chromatography (EtOAc/hexane, 1:2) gave carboxylic acid **8** (16.8 g, 0.025 mol, 86%) as a colorless oil: $[\alpha]^{20}_D$ −37 (*c* 0.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.97−1.10 (22H, m, *i*-Pr, H-3a), 1.86 (1H, m, H-3b), 2.20−2.34 (3H, m, H_2-2, H-4), 2.81 (1H, dd, J = 9.3, 9.3 Hz, H-5a), 3.12 (1H, dd, J = 9.3, 5.6 Hz, H-5b), 3.71 (3H, s, OCH_3), 3.81 (3H, s, OCH_3), 5.23 (1H, d, J = 4.4 Hz, ArCHOSi), 6.56 (2H, s, ArH), 6.83 (1H, s, ArH), 7.20−7.30 (9H, m, ArH), 7.42−7.44 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.3, 18.0, 18.1, 21.3, 32.4, 46.6, 55.7, 64.0, 74.2, 86.9, 110.0, 110.2, 119.3, 127.0, 127.7, 128.7, 134.1, 144.1, 147.8, 148.2, 179.6; *anal*. C, 73.46%, H 8.08%, calcd for $C_{42}H_{54}O_6Si$, C 73.86%, H 7.97%. (4*R*,5*R*)-**8**: $[\alpha]^{20}_D$ +37 (*c* 1.2, $CHCl_3$).

(*S*)-4-Benzyl-3-[(4*S*,5*S*)-5-(3,4-dimethoxyphenyl)-5-(triisopropylsilyloxy)-4-(trityloxymethyl)pentanoyl]-2-oxazolidinone (9). To a solution of carboxylic acid **8** (16.8 g, 0.025 mol) in THF (100 mL) was added Et_3N (3.44 mL, 0.025 mol) and PivCl (3.08 mL, 0.025 mol) at −70 °C, and then the mixture was stirred at 0 °C for 1 h. After cooling to −70 °C, a solution of the lithium salt of (*S*)-4-benzyl-2-oxazolidinone in THF (60 mL), prepared from (*S*)-4-benzyl-2-oxazolidinone (4.33 g, 0.024 mol) and *n*-BuLi (2.6 M in THF, 9.65 mL, 0.025 mol), at −70 °C in THF was added, and then the reaction mixture was stirred at 0 °C for 1 h. After addition of a saturated aqueous NH_4-Cl solution, the solution was separated, washed with brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:3) gave acyloxazolidinone **9** (18.6 g, 0.022 mol, 88%) as a colorless oil: $[\alpha]^{20}_D$ −10 (*c* 0.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.97−1.08 (21H, m, *i*-Pr), 1.14 (1H, m, H-3a of pentanoyl), 1.89 (1H, m, H-3b of pentanoyl), 2.30 (1H, m, H-4 of pentanoyl), 2.58 (1H, dd, J = 13.4, 10.0 Hz, CH_{2a}Ph-4), 2.81−2.98 (3H, m, H_2-2 of pentanoyl, $TrOCH_{2a}$), 3.16 (1H, dd, J = 9.8, 5.4 Hz, $TrOCH_{2b}$), 3.22 (1H, dd, J = 13.4, 3.2 Hz, CH_{2b}Ph), 3.74 (3H, s, OCH_3), 3.82 (3H, s, OCH_3), 4.08−4.10 (2H, m, H_2-5), 4.57 (1H, m, H-4), 5.20 (1H, d, J = 4.4 Hz, ArCHOSi), 6.59 (2H, s, ArH), 6.88 (1H, s, ArH), 7.15−7.17 (2H, m, ArH), 7.20−7.30 (12H, m, ArH), 7.43−7.45 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.4, 18.0, 18.1, 20.9, 34.1, 37.8, 46.9, 55.1, 55.69, 55.73, 64.3, 66.0, 74.5, 86.9, 110.0, 110.3, 119.3, 126.9, 127.2, 127.7, 128.7, 128.9, 129.3, 134.4, 135.4, 144.1, 147.7, 148.2, 153.2, 173.2; *anal*. C 74.14%, H 7.63%, N 1.54%, calcd for $C_{52}H_{63}O_7NSi$, C 74.16%, H 7.54%, N 1.66%. (*R*)-[(4*R*,5*R*)]-**9**: $[\alpha]^{20}_D$ +10 (*c* 1.1, $CHCl_3$).

(*R*)-4-Benzyl-3-[(4*S*,5*S*)-5-(3,4-dimethoxyphenyl)-5-(triisopropylsilyloxy)-4- (trityloxymethyl)pentanoyl]-2-oxazolidinone (19). Yield 83%, colorless oil: $[\alpha]^{20}_D$ −42 (*c* 0.5, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.98−1.08 (21H, m, *i*-Pr), 1.15 (1H, m, H-3a of pentanoyl), 1.89 (1H, m, H-3b of pentanoyl), 2.32 (1H, m, H-4 of pentanoyl), 2.70 (1H, dd, J = 13.6, 9.6 Hz, $PhCH_{2a}$), 2.84−2.98 (1H, overlapped, $TrOCH_{2a}$), 2.91 (2H, t, J = 9.0 Hz, H_2-2 of pentanoyl), 3.17 (1H, dd, J = 9.6, 5.7 Hz, $TrOCH_{2b}$), 3.23 (1H, dd, J = 13.6, 3.2 Hz, $PhCH_{2b}$), 3.74 (3H, s, OCH_3), 3.81 (3H, s, OCH_3), 4.03−4.10 (2H, m, H_2-5), 4.54 (1H, m, H-4), 5.19 (1H, d, J = 4.5 Hz, ArCHOSi), 6.59 (2H, s, ArH), 6.88 (1H, s, ArH), 7.15−7.17 (2H, m, ArH), 7.20−7.32 (7H, m, ArH), 7.43−7.45 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.3, 18.0, 18.1, 20.9, 34.1, 37.8, 46.7, 55.1, 55.66, 55.71, 64.4, 65.9, 74.4, 74.5, 86.9, 110.0, 110.2, 119.3, 126.9, 127.2, 127.7, 128.7, 128.9, 129.3, 134.4, 135.3, 144.1, 147.7, 148.2, 153.1, 173.1; *anal*. C 74.43%, H 7.15%, N 1.60%, calcd for $C_{52}H_{63}O_7NSi$, C 74.16%, H 7.54%, N 1.66%. (*S*)-[(4*R*,5*R*)]-**19**: $[\alpha]^{20}_D$ +42 (*c* 0.7, $CHCl_3$).

(*S*)-4-Benzyl-3-{(*S*)-2-[(2*S*,3*S*)-3-(3,4-dimethoxypheyl)-3-(triisopropylsilyloxy)-2-(trityloxymethyl)prop-1-yl]-4-pentenoyl}-2-oxazolidinone (10). To a solution of KDMDS (26.7 mL, 0.5 M toluene, 0.013 mol) in THF (80 mL) was added a solution of acyloxazolidinone **9** (18.6 g, 0.022 mol) in THF (50 mL) and allyl bromide (2.83 mL, 0.033 mol) at −70 °C. The solution was gradually warmed to room temperature for 16 h. After addition of a saturated aqueous NH_4Cl solution, the organic solution was separated, washed with brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:6) gave allyl compound **10** (9.47 g, 0.011 mol, 50%) as a colorless oil: $[\alpha]^{20}_D$ −25 (*c* 0.9, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.90−1.11 (22H, m, *i*-Pr, C*H*H-2 of pentenoyl), 2.08 (1H, m, CH*H*-2 of pentenoyl), 2.19 (1H, m, *H*H-3 pentenoyl), 2.26−2.39 (2H, m, H*H*-3 pentenoyl, $TrOCH_2CH$), 2.56 (1H, dd, J = 13.2, 10.3 Hz, CH_{2a}Ph), 2.79 (1H, dd, J = 9.3, 9.3 Hz, $TrOCH_{2a}$), 3.12 (1H, dd, J = 9.3, 5.6 Hz, $TrOCH_{2b}$), 3.29 (1H, dd, J = 13.2, 2.9 Hz, CH_{2b}Ph), 3.71 (3H, s, OCH_3), 3.82 (3H, s, OCH_3), 3.82−3.89 (1H, overlapped, H-2 of pentenoyl), 3.95 (1H, dd, J = 9.3, 8.5 Hz, H-5a), 4.05 (1H, dd, J = 9.3, 2.4 Hz, H-5b), 4.52 (1H, m, H-4), 4.93−4.99 (2H, m, H_2-5 of pentenoyl), 5.27 (1H, d, *J* 3.9 Hz, ArCHOSi), 5.69 (1H, m, H-4 of pentenoyl), 6.56 (2H, s, ArH), 6.88 (1H, s, ArH), 7.18−7.36 (14H, m, ArH), 7.40−7.44 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.4, 18.0, 18.1, 28.5, 38.0, 38.2, 39.9, 45.2, 55.5, 55.7, 64.3, 65.7, 74.2, 86.9, 110.0, 110.4, 117.1, 119.3, 126.9, 127.2, 127.7, 128.7, 128.9, 129.3, 134.4, 134.9, 135.7, 144.1, 147.6, 148.1, 152.7, 175.5; *anal*. C 75.12%, H 7.68%, N 1.65%, calcd for $C_{55}H_{67}O_7NSi$, C 74.88%, H 7.66%, N 1.59%. (*R*)-3-{(*R*)-[(2*R*,3*R*)]}-**10**: $[\alpha]^{20}_D$ +25 (*c* 0.3, $CHCl_3$).

(*R*)-4-Benzyl-3-{(*R*)-2-[(2*S*,3*S*)-3-(3,4-dimethoxypheyl)-3-(triisopropylsilyloxy)-2-(trityloxymethyl)prop-1-yl]-4-pentenoyl}-2-oxazolidinone (20). Yield 59%, colorless oil: $[\alpha]^{20}_D$ −34 (*c* 2.7, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.88−1.15 (22H, m, *i*-Pr, CH-2a of pentenoyl), 1.80 (1H, m, CH-2b of pentenoyl), 2.24 (1H, m, H-3a of pentenoyl), 2.31 (1H, m, $TrOCH_2CH$), 2.38 (1H, m, H-3b of pentenoyl), 2.55 (1H, dd, J = 13.3, 10.1 Hz, $PhCH_{2a}$), 2.66 (1H, dd, J = 10.0, 10.0 Hz, $TrOCH_{2a}$), 3.20 (1H, dd, J = 13.3, 3.1 Hz, $PhCH_{2b}$), 3.25 (1H, dd, J = 10.0, 4.9 Hz, $TrOCH_{2b}$), 3.70 (3H, s, OCH_3), 3.76 (1H, m, H-2 of pentenoyl), 3.80 (3H, s, OCH_3), 3.80−3.86 (1H, overlapped, H-5a), 4.01 (1H, dd, J = 8.9, 2.4 Hz, H-5b), 4.41 (1H, m, H-4), 4.99−5.04 (2H, m, H_2-5 of pentenoyl), 5.39 (1H, d, J = 3.8 Hz, ArCHOSi), 5.75 (1H, m, H-4 of pentenoyl), 6.53−6.58 (2H, m, ArH), 6.87 (1H, s, ArH), 7.16−7.18 (2H, m, ArH), 7.20−7.33 (7H, m, ArH), 7.42−7.45 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.3, 18.0, 18.1, 26.8, 36.9, 38.0, 41.0, 45.7, 55.5, 55.6, 55.7, 64.3, 65.6, 73.5, 87.0, 110.0, 110.4, 117.1, 119.3, 126.9, 127.2, 127.7, 128.6, 128.9, 129.3, 133.9, 135.2, 135.5, 144.1, 147.6, 148.0, 152.6, 175.8; *anal*. C 75.01%, H 7.70%, N 1.59%, calcd for $C_{55}H_{67}O_7NSi$, C 74.88%, H 7.66%, N 1.59%. (*S*)-3-{(*S*)-2-[(2*R*,3*R*)]-**20**: $[\alpha]^{20}_D$ +33 (*c* 0.5, $CHCl_3$).

(*S*)-2-[(2*S*,3*S*)-3-(3,4-Dimethoxyphenyl)-3-(triisopropylsilyloxy)-2-(trityloxymethyl)prop-1-yl]-4-penten-1-ol (11). To a solution of $LiBH_4$ (1.75 g, 0.080 mol) and MeOH (1.75 mL) in THF (20 mL) was added acyloxazolidinone **10** (9.47 g, 0.011 mol) in THF (50 mL), and then the reaction solution was stirred at room temperature for 1 h. After addition of a saturated aqueous NH_4Cl solution, the mixture was concentrated. The residue was dissolved in EtOAc and H_2O. The solution was separated, washed with brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:3) gave alcohol **11** (6.97 g, 0.0098 mol, 89%) as a colorless oil: $[\alpha]^{20}_D$ −43 (*c* 0.7, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.53 (1H, m, CH-2a), 0.88−1.13 (21H, m, *i*-Pr), 1.41 (1H, m, CH-2b), 1.49 (1H, m, H-2), 1.57 (1H, br s, OH), 1.94 (1H, m, H-3a), 2.06 (1H, m, H-3b), 2.31 (1H, m, $TrOCH_2CH$), 2.80 (1H, dd, J = 9.5, 9.5 Hz, $TrOCH_{2a}$), 3.13 (1H, dd, J = 9.5, 5.1 Hz, $TrOCH_{2b}$), 3.49 (2H, d, J = 4.9 Hz, H_2-1), 3.73 (3H, s, OCH_3), 3.84 (3H, s, OCH_3), 4.91−4.97 (2H, m, H_2-5), 5.30 (1H, d, J = 3.9 Hz, ArCHOSi), 5.65 (1H, m, H-4), 6.60 (2H, s, ArH), 6.87 (1H, s, ArH), 7.23−7.32 (9H, m, ArH), 7.44−7.46 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.4, 18.0, 18.1, 26.9, 36.9, 38.2, 44.6, 55.7, 64.7, 74.3, 87.0, 109.9, 110.4, 116.1, 119.4, 127.0, 127.7, 128.7, 134.1, 136.9, 144.2, 147.7, 148.1; *anal*. C 76.31%, H 8.57%, calcd for $C_{45}H_{60}O_5Si$, C 76.23%, H 8.53%. (*R*)-[(2*R*,3*R*)]-**11**: $[\alpha]^{20}_D$ +43 (*c* 1.0, $CHCl_3$).

(*R*)-2-[(2*S*,3*S*)-3-(3,4-Dimethoxyphenyl)-3-(triisopropylsilyloxy)-2-(trityloxymethyl)prop-1-yl]-4-penten-1-ol (21). Yield 90%, colorless oil: $[\alpha]^{20}_D$ −24 (*c* 1.2, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.60 (1H, m, CH-2a), 0.99−1.12 (21H, m, *i*-Pr), 1.36−1.45 (2H, m, CH-2b, H-2), 1.60 (1H, br s, OH), 1.94 (1H, m, H-3a), 2.05 (1H, m, H-3b), 2.36 (1H, m, $TrOCH_2CH$), 2.80 (1H, dd, J = 9.5, 9.5 Hz, $TrOCH_{2a}$), 3.16 (1H, dd, J = 9.5, 5.3 Hz, $TrOCH_{2b}$), 3.34 (1H, dd, J = 10.8, 5.4 Hz, H-1a), 3.43 (1H, dd, J = 10.8, 5.4 Hz, H-1b), 3.70 (3H, s, OCH_3), 3.81 (3H, s, OCH_3), 4.96−4.99 (2H, m, 5-H_2), 5.29 (1H, d, J = 4.2 Hz, ArCHOSi), 5.72 (1H, m, 4-H), 6.55−6.58 (2H, m, ArH), 6.84 (1H, s, ArH), 7.21−7.31 (9H, m, ArH), 7.43−7.46 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.4, 18.0, 18.1, 26.5, 35.4, 38.3, 44.1, 55.67, 55.70, 64.7, 65.8, 74.2, 87.0, 109.9, 110.5, 116.1, 119.5, 127.0, 127.7, 128.7, 134.2, 137.0, 144.1, 147.7, 148.1; *anal*. C 76.09%, H 8.55%, calcd for $C_{45}H_{60}O_5Si$, C 76.23%, H 8.53%. (*S*)-2-[(2*R*,3*R*)]-**21**: $[\alpha]^{20}_D$ +24 (*c* 0.5, $CHCl_3$).

(*S*)-2-[(2*S*,3*S*)-3-(3,4-Dimethoxyphenyl)-3-(triisopropylsilyloxy)-2-(trityloxymethyl)prop-1-yl]-4-pentenal (12). A mixture of alcohol **11** (6.97 g, 0.0098 mol), PCC (2.66 g, 0.012 mol), and molecular sieves 4 Å (0.1 g) in CH_2Cl_2 (150 mL) was stirred at room temperature for 16 h before addition of dry Et_2O. After filtration, the filtrate was concentrated. The residue was applied to silica gel column chromatography (EtOAc/hexane, 1:5) to give aldehyde **12** (5.21 g, 0.0074 mol, 76%) as colorless crystals, mp 98−99 °C (*i*-Pr_2O): $[\alpha]^{20}_D$ −29 (*c* 1.2, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.79 (1H, m CH-2a), 0.92−1.10 (21H,

m, *i*-Pr), 1.88 (1H, m, CH-2b), 2.10 (1H, m, TrOCH$_2$C*H*), 2.22−2.31 (3H, m, H-2, H$_2$-3), 2.81 (1H, dd, J = 9.3, 9.3 Hz, TrOCH$_{2a}$), 3.11 (1H, dd, J = 9.3, 5.4 Hz, TrOCH$_{2b}$), 3.71 (3H, s, OCH$_3$), 3.82 (3H, s, OCH$_3$), 4.93−4.97 (2H, m, H$_2$-5), 5.23 (1H, d, J = 4.4 Hz, ArCHOSi), 5.58 (1H, m, H-4), 6.57 (2H, s, ArH), 6.82 (1H, s, ArH), 7.21−7.32 (9H, m, ArH), 7.40−7.43 (6H, m, ArH**),** 9.46 (1H, d, J = 2.9 Hz, CHO); ^{13}C NMR (CDCl$_3$) δ 12.3, 12.5, 17.9, 18.0, 18.1, 25.6, 34.1, 44.7, 49.1, 55.7, 55.8, 64.1, 74.3, 87.0, 110.0, 110.2, 117.1, 119.3, 127.0, 127.2, 127.7, 127.9, 128.6, 133.9, 134.7, 144.0, 146.9, 147.8, 148.2, 204.5; *anal*. C 76.46%, H 8.29%, calcd for $C_{45}H_{58}O_5Si$, C 76.44%, H 8.27%. (*R*)-[(2*R*,3*R*)]-**12**: $[\alpha]^{20}_D$ +28 (*c* 0.7, CHCl$_3$).

(*R*)-2-[(2*S*,3*S*)-3-(3,4-Dimethoxyphenyl)-3-(triisopropylsilyloxy)-2-(trityloxymethyl)prop-1-yl]-4-pentenal (22). Yield 100%, colorless oil: $[\alpha]^{20}_D$ −30 (*c* 1.2, CHCl$_3$); ^{1}H NMR (CDCl$_3$) δ 0.88−1.56 (22H, m, *i*-Pr, CH$_{2a}$-3), 1.53 (1H, m, CH$_{2b}$-3), 2.17 (1H, m, H-3a), 2.26 (1H, m, H-3b), 2.31−2.38 (2H, m, H-2, TrOCH$_2$C*H*), 2.83 (1H, dd, J = 9.4, 9.4 Hz, TrOCH$_{2a}$), 3.11 (1H, dd, J = 9.7, 5.5 Hz, TrOCH$_{2b}$), 3.71 (3H, s, OCH$_3$), 3.82 (3H, s, OCH$_3$), 4.99−5.03 (2H, m, H$_2$-5), 5.28 (1H, d, J = 4.2 Hz, ArCHOSi), 5.67 (1H, m, H-4), 6.58 (2H, s, ArH), 6.82 (1H, s, ArH), 7.21−7.32 (9H, m, ArH), 7.42−7.44 (6H, m, ArH), 9.47 (1H, d, J = 2.1 Hz, CHO); ^{13}C NMR (CDCl$_3$) δ 12.3, 17.95, 18.04, 24.7, 33.1, 44.6, 49.3, 55.6, 64.1, 74.1, 86.9, 110.0, 110.2, 117.0, 119.3, 126.9, 127.1, 127.7, 127.79, 127.80, 128.5, 133.8, 134.8, 143.9, 146.8, 147.7, 148.1, 204.4; *anal*. C 76.64%, H 8.01%, calcd for $C_{45}H_{58}O_5Si$, C 76.44%, H 8.27%. (*S*)-2-[(2*R*,3*R*)]-**22**: $[\alpha]^{20}_D$ +31 (*c* 0.8, CHCl$_3$).

(1*R*,2*S*,4*S*)-2-Allyl-5-hydroxy-1-(3,4-dimethoxyphenyl)-4-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]pentyl Acetate (14) and (1*S*,2*S*,4*S*)-2-Allyl-5-hydroxy-1-(3,4-dimethoxyphenyl)-4-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]pentyl Acetate (15). A mixture of Mg (6.08 g, 0.25 mol) and 1-bromo-3,4-dimethoxybenzene (5.07 mL, 35.3 mmol) in THF (150 mL) was heated under reflux for 1 h before aldehyde **12** (1.98 g, 2.80 mmol) in THF (50 mL) was added at 0 °C. After stirring at room temperature for 1 h, a saturated aqueous NH$_4$Cl solution was added. The solution was separated, washed with brine, and dried (Na$_2$SO$_4$). Concentration followed by silica gel column chromatography (10% EtOAc/toluene and EtOAc/hexane, 1:1) gave Grignard product **13** (2.21 g, 2.61 mmol, 93%) as a diastereomeric mixture (found C, 75.38; H, 8.19; $C_{53}H_{68}O_7Si$ requires C, 75.32; H, 8.11). A solution of Grignard product (2.21 g, 2.61 mmol) in pyridine (7 mL) and Ac$_2$O (7 mL) was stirred at room temperature for 16 h, and then ice was added. After 6 h, the mixture was dissolved in CHCl$_3$ and H$_2$O. The organic solution was separated, washed with 1 M aqueous HCl solution, saturated aqueous NaHCO$_3$ solution, and brine, and dried (Na$_2$SO$_4$). Concentration gave a crude acetate. To a solution of the crude acetate in ether (24 mL) was added HCO$_2$H (36 mL) at −5 °C. After stirring at −5 °C for 10 min, CHCl$_3$ and H$_2$O were added. The organic solution was separated, washed with a saturated aqueous NaHCO$_3$ solution and brine, and dried (Na$_2$SO$_4$). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:1) gave acetate **14** (0.64 g, 0.99 mmol, 35%) as a colorless oil and acetate **15** (0.68 g, 1.05 mmol, 38%) as a colorless oil. **14**: $[\alpha]^{20}_D$ −2 (*c* 1.6, CHCl$_3$); ^{1}H NMR (CDCl$_3$) δ 0.95−1.00 (21H, m, *i*-Pr), 1.11 (1H, m, CH$_{2a}$CHCH$_2$OH), 1.42 (1H, m, CH$_{2b}$CHCH$_2$OH), 1.73 (1H, m, Ar(AcO)CHC*H*), 1.90 (1H, m, CH$_2$=CHCH$_{2a}$), 1.96 (3H, s, Ac), 2.01 (1H, m, CH$_2$=CHCH$_{2b}$), 2.16 (1H, m, HOCH$_2$C*H*), 2.85 (1H, br s, OH), 3.61 (1H, m, HOCH$_{2a}$), 3.84−3.92 (1H, overlapped, HOCH$_{2b}$), 3.84 (3H, s, OCH$_3$), 3.85 (3H, s, OCH$_3$), 3.87 (3H, s, OCH$_3$), 3.88 (3H, s, OCH$_3$), 4.64 (1H, d, J = 5.9 Hz, ArCHOAc), 4.97−5.02 (2H, m, C*H*$_2$=CH), 5.64 (1H, d, J = 5.9 Hz, ArCHOSi), 5.69 (1H, m, CH$_2$=C*H*), 6.68−6.70 (3H, m, ArH), 6.76−6.78 (2H, m, ArH), 6.82 (1H, d, *J* 2.0 Hz, ArH); ^{13}C NMR (CDCl$_3$) δ 12.5, 17.9, 18.0, 20.8, 28.4, 34.2, 41.0, 45.9, 55.68, 55.74, 55.8, 62.9, 76.3, 80.2, 109.7, 110.3, 110.8, 116.7, 118.7, 119.1, 132.0, 136.0, 136.4, 148.2, 148.3, 148.6, 148.7, 169.8; *anal*. C 67.01%, H 8.66%, calcd for $C_{36}H_{56}O_8Si$, C 67.05%, H 8.75%. (1*S*,2*R*,4*R*)-4-[(*R*)]-**14**: $[\alpha]^{20}_D$ +2 (*c* 0.6, CHCl$_3$). **15**: $[\alpha]_D^{20}$ −52 (*c* 0.6, CHCl$_3$); ^{1}H NMR (CDCl$_3$) δ 0.96−1.01 (21H, m, *i*-Pr), 1.30−1.39 (2H, m, C*H*$_2$CHCH$_2$OH), 1.79 (1H, m, Ar(AcO)CHC*H*), 1.89 (1H, m, HOCH$_2$C*H*), 1.96 (1H, m, CH$_2$=CHCH$_{2a}$), 2.01 (3H, s, Ac), 2.17 (1H, m, CH$_2$=CHCH$_{2b}$), 3.60 (1H, dd, J = 11.0, 6.1 Hz, HOCH$_{2a}$), 3.78−3.89 (1H, overlapped, HOCH$_{2b}$), 3.84 (3H, s, OCH$_3$), 3.86 (3H, s, OCH$_3$), 3.88 (3H, s, OCH$_3$), 3.89 (3H, s, OCH$_3$), 4.75 (1H, d, J = 5.9 Hz, ArCHOAc), 4.93−5.04 (2H, m, C*H*$_2$=CH), 5.56 (1H, d, J = 6.4 Hz, ArCHOSi), 5.71 (1H, m, CH$_2$=C*H*), 6.55 (1H, dd, J = 8.3, 2.0 Hz, ArH), 6.68−6.73 (3H, m, ArH), 6.77 (1H, d, J = 8.3 Hz, ArH), 6.91 (1H, d, J = 2.0 Hz, ArH); ^{13}C NMR (CDCl$_3$) δ 12.6, 18.0, 18.1, 21.2, 28.0, 34.9, 40.9, 46.4, 55.79, 55.82, 55.86, 63.6, 77.6, 79.5, 110.0, 110.4, 110.6, 117.2, 119.3, 119.5, 131.5, 135.8, 136.0, 148.3, 148.5, 148.7, 170.0; *anal*. C 67.01%, H 8.74%, calcd for $C_{36}H_{56}O_8Si$, C 67.05%, H 8.75%. (1*R*,2*R*,4*R*)-4-[(*R*)]-**15**, $[\alpha]^{20}_D$ +52 (*c* 0.7, CHCl$_3$).

(1*S*,2*R*)-1-(3,4-Dimethoxyphenyl)-2-[(2*S*,3*S*)-3-(3,4-dimethoxyphenyl)-3-(triisopropylsilyloxy)-2-(trityloxymethyl)prop-1-yl]-4-penten-1-ol (23) and (1*R*,2*R*)-1-(3,4-Dimethoxyphenyl)-2-[(2*S*,3*S*)-3-(3,4-dimethoxyphenyl)-3-(triisopropylsilyloxy)-2-(trityloxymethyl)prop-1-yl]-4-penten-1-ol (24). To a solution of 3,4-dimethoxyphenylmagnesium bromide (18 mL, 0.5 M in THF, 9.00 mmol) in THF (20 mL) was added aldehyde **22** (2.96 g, 4.19 mmol) in THF (40 mL) at 0 °C. After the reaction solution was stirred at room temperature for 1 h, a saturated aqueous NH$_4$Cl solution was added. The organic solution was separated, washed with brine, and dried (Na$_2$SO$_4$). Concentration followed by silica gel column chromatography (10% EtOAc in toluene) gave **23** (0.98 g, 1.16 mmol, 28%) as a colorless oil and **24** (0.92 g, 1.09 mmol, 26%) as a colorless oil. **23**: $[\alpha]^{20}_D$ −26 (*c* 1.5, CHCl$_3$); ^{1}H NMR (CDCl$_3$) δ 0.48 (1H, m, CH-2a), 0.96−1.05 (21H, m, *i*-Pr), 1.44 (1H, m, CH-2b), 1.53 (1H, m, H-2), 1.89 (1H, br s, OH), 2.05 (1H, m, H-3a), 2.20 (1H, m, H-3b), 2.31 (1H, m, TrOCH$_2$C*H*), 2.67 (1H, dd, J = 9.3, 9.3 Hz, TrOCH$_{2a}$), 3.01 (1H, dd, J = 9.3, 5.2 Hz, TrOCH$_{2b}$), 3.66 (3H, s, OCH$_3$), 3.68 (3H, s, OCH$_3$), 3.80 (3H, s, OCH$_3$), 3.83 (3H, s, OCH$_3$), 4.42 (1H, d, J = 6.2 Hz, ArC*H*OH), 5.04−5.10 (2H, m, C*H*$_2$=CH), 5.17 (1H, d, J = 4.2 Hz, ArCHOSi), 5.82 (1H, m, CH$_2$=C*H*), 6.43−6.53 (2H, m, ArH), 6.57−6.65 (2H, m, ArH), 6.69 (1H, d, J = 8.5 Hz, ArH), 6.76 (1H, d, J = 1.6 Hz, ArH), 7.20−7.30 (9H, m, ArH), 7.39−7.43 (6H, m, ArH); ^{13}C NMR (CDCl$_3$) δ 12.4, 18.0, 18.1, 26.1, 33.8, 42.9, 44.9, 55.66, 55.71, 55.74, 64.4, 74.4, 75.7, 87.0, 100.6, 105.7, 109.4, 109.8, 110.3, 110.6, 116.2, 118.6, 119.3, 126.9, 127.7, 128.6, 134.4, 135.5, 137.3, 144.1, 147.6, 148.0, 148.5; *anal*. C 75.08%, H 8.08%, calcd for $C_{53}H_{68}O_7Si$, C 75.32%, H 8.11%. (1*R*,2*S*)-2-[(2*R*,3*R*)]-**23**: $[\alpha]^{20}_D$ +26 (*c* 0.3, CHCl$_3$). **24**: $[\alpha]^{20}_D$ −12 (*c* 1.3, CHCl$_3$); ^{1}H NMR (CDCl$_3$) δ 0.67 (1H, m, CH-2a), 0.96−1.13 (21H, m, *i*-Pr), 1.51−1.60 (2H, m, CH-2b, H-2), 1.90−2.14 (2H, m, OH, H-3a), 2.12 (1H, m, H-3b), 2.33 (1H, m, TrOCH$_2$C*H*), 2.47 (1H, dd, J = 9.6, 4.4 Hz, TrOCH$_{2a}$), 2.88 (1H, d, J = 9.6, 4.4 Hz, TrOCH$_{2b}$), 3.63 (3H, s, OCH$_3$), 3.68 (3H, s, OCH$_3$), 3.80 (3H, s, OCH$_3$), 3.82 (3H, s, OCH$_3$), 4.51 (1H, d, J = 4.2 Hz, ArC*H*OH), 4.93−5.01 (2H, m, C*H*$_2$=CH), 5.26 (1H, d, J = 3.7 Hz, ArCHOSi), 5.77 (1H, m, CH$_2$=C*H*), 6.44−6.52 (3H, m, ArH), 6.57 (1H, d, J = 8.2 Hz, ArH), 6.62 (1H, d, J = 1.8 Hz, ArH), 6.79 (1H, s, ArH), 7.21−7.29 (9H, m, ArH), 7.35−7.37 (6H, m, ArH); ^{13}C NMR (CDCl$_3$) δ 12.4, 18.0, 18.1, 24.2, 35.2, 43.6, 44.8, 55.6, 55.7, 64.2, 74.1, 75.4, 86.8, 109.3, 109.8, 110.5, 116.2, 118.4, 119.4, 126.9, 127.6, 128.7, 134.1, 136.0, 137.2, 144.1, 147.6, 147.8, 147.9, 148.6; *anal*. C 75.21%, H 8.09%, calcd for $C_{53}H_{68}O_7Si$, C 75.32%, H 8.11%. (1*S*,2*S*)-2-[(2*R*,3*R*)]-**24**: $[\alpha]^{20}_D$ +12 (*c* 0.3, CHCl$_3$).

(1*S*,2*R*,4*S*)-2-Allyl-5-hydroxy-1-(3,4-dimethoxyphenyl)-4-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]pentyl Acetate (25). A solution of Grignard product **23** (0.86 g, 1.02 mmol) in pyridine (5 mL) and Ac$_2$O (5 mL) was stirred at room temperature for 16 h, and then ice was added. After 6 h, the mixture was dissolved in CHCl$_3$ and H$_2$O. The organic phase was separated, washed with 1 M aqueous HCl solution, a saturated aqueous NaHCO$_3$ solution, and brine, and dried (Na$_2$SO$_4$). Concentration gave a crude acetate. To a solution of the crude acetate in ether (10 mL) was added HCO$_2$H (15 mL) at −5 °C. After stirring at −5 °C for 10 min, CHCl$_3$ and H$_2$O were added. The organic solution was separated, washed with a saturated aqueous NaHCO$_3$ solution and brine, and dried (Na$_2$SO$_4$). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:1) gave alcohol **25** (0.38 g, 0.59 mmol, 58%) as a colorless oil: $[\alpha]^{20}_D$ +4 (*c* 0.5, CHCl$_3$); ^{1}H NMR (CDCl$_3$) δ 0.91−0.93 (21H, m, *i*-Pr), 1.01 (1H, m, H-3a), 1.16 (1H, m, H-3b), 1.80 (1H, m, H-2), 1.98−2.07 (1H, overlapped, CH$_2$=CH−CH$_{2a}$), 2.02 (3H, s, Ac), 2.19 (1H, m, H-4), 2.20 (1H, m, CH$_2$=CH−CH$_{2b}$), 2.68 (1H, br s, OH), 3.45 (1H, m, H-5a), 3.69 (1H, m, H-5b), 3.858 (3H, s, OCH$_3$), 3.864 (3H, s, OCH$_3$), 3.87 (3H, s, OCH$_3$), 3.88 (3H, s, OCH$_3$), 4.67 (1H, d, J = 5.9 Hz, H-1), 4.87−4.99 (2H, m, C*H*$_2$=CH), 5.51 (1H, d, J = 8.3 Hz, ArCHOSi), 5.62 (1H, m, CH$_2$=C*H*), 6.73−6.86 (6H, m, ArH); *anal*. C 66.92%, H 8.63%, calcd for $C_{36}H_{56}O_8Si$, C 67.05%, H 8.75%.

(1*R*,2*R*,4*S*)-2-Allyl-5-hydroxy-1-(3,4-dimethoxyphenyl)-4-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]pentyl Acetate (26). Yield 59%, colorless oil: $[\alpha]^{20}_D$ +15 (*c* 0.8, CHCl$_3$); ^{1}H NMR (CDCl$_3$) δ 0.92−1.02 (21H, m, *i*-Pr), 1.24 (1H, m, CH-2a), 1.46 (1H,

m, CH-2b), 1.77 (1H, m, H-2), 1.82−2.00 (3H, m, H-4, CH_2═CHCH_2), 2.04 (3H, s, Ac), 2.86 (1H, br dd, J = 6.1, 6.1 Hz, OH), 3.53 (1H, m, H-5a), 3.74 (1H, m, H-5b), 3.86 (6H, s, OCH_3), 3.89 (6H, s, OCH_3), 4.76−4.80 (2H, m, CH_2═CH), 4.91 (1H, d, J = 10.0 Hz, ArCHOAc), 5.52 (1H, m, CH_2═CH), 5.56 (1H, d, J = 7.3 Hz, ArCHOSi), 6.77−6.84 (5H, m, ArH), 6.93 (1H, s, ArH); ^{13}C NMR ($CDCl_3$) δ 12.5, 17.9, 18.0, 21.2, 27.5, 34.1, 40.6, 46.2, 55.79, 55.84, 55.88, 62.9, 77.8, 80.0, 109.9, 110.1, 110.4, 110.8, 117.1, 119.3, 119.5, 131.8, 134.9, 135.9, 148.4, 148.6, 148.7, 148.8, 170.2; *anal*. C 66.85%, H, 8.45%, calcd for $C_{36}H_{56}O_8Si$, C 67.05%, H 8.75%. (1*S*,2*S*,4*R*)-4-[(*R*)]-**26**: $[\alpha]^{20}_D$ −15 (*c* 0.4, $CHCl_3$).

(2*R*,3*S*,5*S*)-3-Allyl-2-(3,4-dimethoxyphenyl)-5-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]tetrahydropyran (16). To an ice-cooled solution of alcohol **14** (0.35 g, 0.54 mmol) and Et_3N (84 μL, 0.60 mmol) in CH_2Cl_2 (1 mL) was added MsCl (46 μL, 0.59 mmol), and then the reaction mixture was stirred at 0 °C for 30 min. After addition of CH_2Cl_2 and H_2O, the organic solution was separated, washed with saturated aqueous $NaHCO_3$ and brine, and dried (Na_2SO_4). Concentration gave a crude mesylate. A mixture of the crude mesylate and K_2CO_3 (0.32 g, 2.32 mmol) in MeOH (5 mL) was stirred at room temperature for 6 h, and then H_2O and EtOAc were added. The organic phase was separated, washed with brine, and dried (Na_2SO_4). Concentration gave a crude hydroxy mesylate. To a suspension of NaH (0.10 g, 60% oil suspension, 2.50 mmol) in DMF (5 mL) was added a solution of the crude hydroxy mesylate in DMF (1 mL) at 0 °C. After stirring at room temperature for 16 h, EtOAc and H_2O were added. The organic phase was separated, washed with brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:4) gave tetrahydropyran **16** (0.22 g, 0.38 mmol, 70%) as a colorless oil: $[\alpha]^{20}_D$ +6 (*c* 0.8, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.88 (1H, m, H-4a (H-9a)), 0.94−1.01 (21H, m, *i*-Pr), 1.32 (1H, m, H-4b (H-9b)), 1.74 (1H, m, H-3 (H-8)), 1.82 (1H, m, CH_2═$CHCH_{2a}$), 2.00 (1H, m, CH_2═$CHCH_{2b}$), 2.20 (1H, m, H-5 (H-8′)), 3.42 (1H, dd, J = 11.2, 11.2 Hz, H-6a (H-9′a)), 3.86 (3H, s, OCH_3), 3.87 (3H, s, OCH_3), 3.877 (3H, s, OCH_3), 3.882 (3H, s, OCH_3), 4.42 (1H, d, J = 7.3 Hz, ArCHOSi), 4.45 (1H, d, J = 2.0 Hz, H-2 (H-7)), 4.51 (1H, dd, J = 11.2, 2.4 Hz, H-6b (H-9′b)), 4.74−4.82 (2H, m, CH_2═CH), 5.35 (1H, m, CH_2═CH), 6.72 (1H, dd, J = 8.1, 2.0 Hz, ArH), 6.74−6.84 (4H, m, ArH), 6.87 (1H, d, J = 2.0 Hz, ArH); *anal*. C 69.79%, H 8.98%, calcd for $C_{34}H_{52}O_6$-Si, C 69.82%, H 8.96%.

(2*S*,3*R*,5*S*)-3-Allyl-2-(3,4-dimethoxyphenyl)-5-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]tetrahydropyran (27). Yield 95%, colorless oil: $[\alpha]^{20}_D$ +54 (*c* 1.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.94−1.01 (21H, m, *i*-Pr), 1.44 (1H, m, H-4a (H-9a)), 1.68 (1H, m, H-4b (H-9b)), 1.84−1.95 (2H, m, H-3 (H-8), H-5 (H-8′)), 1.95−2.11 (2H, m, CH_2═CHCH_2), 3.79−3.83 (1H, overlapped, H-6a (H-9a)), 3.81 (3H, s, OCH_3), 3.868 (3H, s, OCH_3), 3.872 (3H, s, OCH_3), 3.88 (3H, s, OCH_3), 4.01 (1H, dd, J = 11.2, 7.3 Hz, H-6b (H-9′b)), 4.66 (1H, d, J = 4.9 Hz, H-2 (H-7)), 4.71 (1H, d, J = 8.3 Hz, ArCHOSi), 4.73−4.82 (2H, m, CH_2═CH), 5.48 (1H, m, CH_2═CH), 6.78−6.80 (3H, m, ArH), 6.84−6.85 (2H, m, ArH), 6.90 (1H, s, ArH); *anal*. C 69.94%, H 8.92%, calcd for $C_{34}H_{52}O_6Si$, C 69.82%, H 8.96%.

(2*S*,3*S*,5*S*)-3-Allyl-2-(3,4-dimethoxyphenyl)-5-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]tetrahydropyran (17). To an ice-cooled solution of alcohol **15** (0.22 g, 0.34 mmol) and Et_3N (53 μL, 0.38 mmol) in CH_2Cl_2 (1 mL) was added MsCl (29 μL, 0.37 mmol), and then the reaction mixture was stirred at 0 °C for 30 min. After addition of CH_2Cl_2 and H_2O, the organic phase was separated, washed with a saturated aqueous $NaHCO_3$ and brine, and dried (Na_2SO_4). Concentration gave a crude mesylate. A mixture of the crude mesylate and K_2CO_3 (0.40 g, 2.89 mmol) in MeOH (5 mL) was stirred at room temperature for 16 h, and then H_2O and EtOAc were added. The organic phase was separated, washed with brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:4) gave tetrahydropyran **17** (0.11 g, 0.19 mmol, 56%) as a colorless oil: $[\alpha]^{20}_D$ −10 (*c* 0.8, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.95−1.05 (21H, m, *i*-Pr), 1.23 (1H, m, H-4a (H-9a)), 1.38 (1H, m, H-4b (H-9b)), 1.52 (1H, m, H-3 (H-8)), 1.74 (1H, m, CH_2═$CHCH_{2a}$), 1.78−1.83 (2H, m, CH_2═$CHCH_{2b}$, H-5 (H-8′)), 3.66 (1H, dd, J = 11.5, 2.7 Hz, H-6a (H-9′a)), 3.88 (6H, s, OCH_3), 3.89 (3H, s, OCH_3), 3.91 (3H, s, OCH_3), 3.91−3.94 (1H, overlapped, H-2 (H-7)), 4.59 (1H, br d, J = 11.5 Hz, H-6b (H-9′b)), 4.75−4.81 (2H, m, CH_2═CH), 5.08 (1H, d, J = 10.3 Hz, ArCHOSi), 5.40 (1H, m, CH_2═CH), 6.77−6.91 (4H, m, ArH), 6.93−6.94 (2H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 12.6, 17.9, 18.1, 30.6, 36.4, 38.1, 43.7, 55.7, 55.8, 55.86, 55.88, 68.5, 74.0, 85.7, 109.6, 110.1, 110.7, 116.3, 119.4, 119.9, 134.1, 135.5, 137.0, 148.4, 148.6, 148.9, 149.0; *anal*. C 69.99%, H 9.04%, calcd for $C_{34}H_{52}O_6Si$, C 69.82%, H 8.96%. (2*R*,3*R*,5*R*)-5-[(*R*)]-**17**: $[\alpha]^{20}_D$ +11 (*c* 0.6, $CHCl_3$).

(2*R*,3*R*,5*S*)-3-Allyl-2-(3,4-dimethoxyphenyl)-5-[(*S*)-(3,4-dimethoxyphenyl)(triisopropylsilyloxy)methyl]tetrahydropyran (28). Yield 54%, colorless oil: $[\alpha]^{20}_D$ −19 (*c* 0.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.95−1.03 (21H, m, *i*-Pr), 1.58−1.66 (4H, m, H-3 (H-8), H_2-4 (H_2-9), CH_2═$CHCH_{2a}$), 1.82 (1H, m, CH_2═$CHCH_{2b}$), 2.10 (1H, m, H-5 (H-8′)), 3.32 (1H, dd, J = 11.0, 11.0, H-6a (H-9′a)), 3.77 (1H, d, J = 9.3 Hz, H-2 (H-7)), 3.86 (3H, s, OCH_3), 3.87 (3H, s, OCH_3), 3.88 (3H, s, OCH_3), 3.89 (3H, s, OCH_3), 4.39 (1H, br d, J = 11.0 Hz, H-6b (H-9′b)), 4.48 (1H, d, J = 7.3 Hz, ArCHOSi), 4.79−4.88 (2H, m, CH_2═CH), 5.51 (1H, m, CH_2═CH), 6.75 (1H, dd, J = 8.2, 1.7 Hz, ArH), 6.78−6.84 (4H, m, ArH), 6.90 (1H, d, J = 1.5 Hz, ArH); ^{13}C NMR ($CDCl_3$) δ 12.5, 18.1, 32.2, 36.5, 41.0, 45.1, 55.8, 71.5, 77.4, 85.3, 109.7, 109.8, 110.2, 110.8, 116.2, 119.1, 120.1, 133.5, 135.6, 136.0, 148.2, 148.6, 148.7, 149.0; *anal*. C 69.54%, H 8.95%, calcd for $C_{34}H_{52}O_6Si$, C 69.82%, H 8.96%. (2*S*,3*S*,5*R*)-5-[(*R*)]-**28**: $[\alpha]^{20}_D$ +19 (*c* 0.2, $CHCl_3$).

(2*S*,3*S*,5*S*)-3-(3,4-Dimethoxycinnamyl)-2-(3,4-dimethoxyphenyl)-5-[(*S*)-(3,4- dimethoxyphenyl)(triisopropylsilyloxy)methyl]tetrahydropyran (18). A reaction solution of olefin **17** (0.21 g, 0.36 mmol), 1-bromo-3,4-dimethoxybenzene (0.17 g, 0.78 mmol), Et_3N (0.23 mL, 1.65 mmol), and $PdCl_2(PPh_3)_2$ (35 mg, 0.050 mmol) in DMF (0.5 mL) was heated at 90 °C under N_2 gas for 6 h before addition of H_2O and EtOAc. The organic solution was separated, washed with brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:6 and 1:1) gave recovered olefin **17** (0.15 g, 0.21 mmol, 58%) and cinnamyl **18** (88 mg, 0.12 mmol, 33%) as a colorless oil: $[\alpha]^{20}_D$ +38 (*c* 0.5, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.88−1.08 (22H, m, *i*-Pr, H-4a (H-9a)), 1.29 (1H, m, H-4b (H-9b)), 1.65 (1H, m, H-3 (H-8)), 1.72−1.82 (2H, m, ArCH═CHCH_2), 1.95 (1H, m, H-5 (H-8′)), 3.69 (1H, dd, J = 11.5, 2.7 Hz, H-6a (H-9′a)), 3.74 (3H, s, OCH_3), 3.82 (3H, s, OCH_3), 3.847 (3H, s, OCH_3), 3.850 (3H, s, OCH_3), 3.89 (3H, s, OCH_3), 3.92 (3H, s, OCH_3), 3.97 (1H, d, J = 9.3 Hz, H-2 (H-7)), 4.60 (1H, d, J = 1l.5 Hz, H-6b (H-9′b)), 5.10 (1H, d, J = 10.3 Hz, ArCHOSi), 5.65 (1H, m, ArCH═CHCH$_2$), 6.04 (1H, d, J = 16.1 Hz, ArCH═CHCH$_2$), 6.58 (1H, d, J = 8.3 Hz, ArH), 6.65−6.66 (2H, m, ArH), 6.68−6.78 (2H, m, ArH), 6.84−6.92 (3H, m, ArH), 6.97 (1H, d, J = 1.6 Hz, ArH); ^{13}C NMR ($CDCl_3$) δ 12.6, 18.0, 18.1, 31.1, 35.4, 39.2, 43.8, 55.6, 55.7, 55.79, 55.83, 55.9, 68.5, 73.9, 85.8, 108.6, 110.2, 110.8, 111.1, 118.6, 119.4, 120.0, 125.7, 130.8, 131.0, 134.1, 136.9, 148.29, 148.31, 148.67, 148.9, 149.0; *anal*. C 69.73%, H 8.41%, calcd for $C_{42}H_{60}O_8Si$, C 69.97%, H 8.39%. (2*R*,3*R*,5*R*)-5-[(*R*)]-**18**: $[\alpha]^{20}_D$ −37 (*c* 0.4, $CHCl_3$).

(2*S*,3*S*,5*S*)-5-[(*S*)-(Hydroxy)(3,4-dimethoxyphenyl)methyl]-3-(3,4-dimethoxycinnamyl)-2-(3,4-dimethoxyphenyl)tetrahydropyran [(+)-morinol B]. A solution of silyl ether (88 mg, 0.12 mmol) and TBAF (0.21 mL, 1 M in THF, 0.21 mmol) in THF (2 mL) was stirred at room temperature for 3 h before addition of a saturated aqueous NH_4-Cl solution and EtOAc. The solution was separated, washed with a saturated aqueous $CuSO_4$ solution, $NaHCO_3$ solution, and brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 4:1) gave (+)-morinol B (51 mg, 0.12 mmol, 100%) as a colorless oil: $[\alpha]^{20}_D$ +69 (*c* 0.7, $CHCl_3$). NMR data agreed with that of described morinol B.[1,2] HPLC, DAICEL chiral column OD-H, detected at 272 nm, 1 mL min^{-1}, 50% *i*-PrOH in hexane, t_R 19 min, >99% ee. (−)-Morinol B: $[\alpha]_D^{20}$ −69 (*c*1.0, $CHCl_3$), t_R 28 min, >99% ee.

(2*R*,3*R*,5*S*)-3-Allyl-5-[(*S*)-(hydroxy)(3,4-dimethoxyphenyl)methyl]-2-(3,4- dimethoxyphenyl)tetrahydropyran (29). Yield 94%, a colorless oil: $[\alpha]^{20}_D$ −5 (*c* 0.7, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 1.00 (1H, ddd, J = 12.1, 12.1, 12.1 Hz, H-4a (H-9a)), 1.56−1.71 (3H, m, H-3 (H-8), H-4b (H-9b), CH_2═$CHCH_{2a}$), 1.82 (1H, m, CH_2═$CHCH_{2b}$), 1.95 (1H, br s, OH), 2.15 (1H, m, H-5 (H-8′)), 3.37 (1H, dd, J = 11.2, 11.2, H-6a (H-9′a)), 3.81 (1H, d, J = 9.6 Hz, H-2 (H-7)), 3.85 (3H, s, OCH_3), 3.87 (3H, s, OCH_3), 3.88 (3H, s, OCH_3), 3.90 (3H, s, OCH_3), 4.33 (1H, d, J = 7.9 Hz, ArCHOH), 4.40 (1H, dd, J = 11.2, 2.3 Hz, H-6b (H-9′b)), 4.79−4.89 (2H, m, CH_2═CH), 5.50 (1H, m, CH_2═CH), 6.79−6.90 (6H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 32.5, 36.4, 41.0, 43.3, 55.8, 55.9, 71.1, 85.2, 109.3, 110.2, 110.8, 116.3, 118.7, 120.1, 133.4, 135.4, 135.5, 148.6, 148.7, 148.95, 149.0; HREIMS *m*/*z* 428.2197 (calcd for $C_{25}H_{32}O_6$, 428.2198). (2*S*,3*S*,5*R*)-5-[(*R*)]-**29**: $[\alpha]^{20}_D$ +5 (*c* 0.6, $CHCl_3$).

(2*R*,3*R*,5*S*)-5-[(*S*)-(Hydroxy)(3,4-dimethoxyphenyl)methyl]-3-(3,4-dimethoxycinnamyl)-2-(3,4-dimethoxyphenyl)tetrahydropyran [(−)-

Morinol A]. Recovered olefin **29** (67%) and (−)-morinol A (31%) as a colorless oil: $[\alpha]^{20}_D$ −15 (*c* 0.4, $CHCl_3$); NMR data agreed with those of naturally occurring morinol A. HPLC, DAICEL chiral column OD-H, detected at 272 nm, 1 mL min^{-1}, 50% *i*-PrOH in hexane, t_R 41 min, >99% ee. (+)-Morinol **A**: $[\alpha]^{20}_D$ +15 (*c* 0.6, $CHCl_3$), t_R 34 min, >99% ee.

(*S*)-4-Benzyl-3-{(*S*)-2-[(*S*)-(hydroxy)(3,4-dimethoxyphenyl)methyl]-5-hexenoyl}-2-oxazolidinone (30). To a solution of oxazolidinone **3** (10.6 g, 0.039 mol) in CH_2Cl_2 (150 mL) were added Bu_2BOTf (48.6 mL, 1 M in CH_2Cl_2, 0.049 mol) and Et_3N (6.30 mL, 0.045 mol) below 0 °C. After cooling to −65 °C, a solution of 3,4-dimethoxybenzaldehyde (7.61 g, 0.046 mol) in CH_2Cl_2 (50 mL) was added. The solution was stirred at −65 °C for 20 min and warmed to 0 °C. After stirring at 0 °C for 1 h, phosphate buffer (50 mL), MeOH (140 mL), and 2:1 MeOH/30% H_2O_2 (140 mL) were added, and the mixture was stirred at 0 °C for 1 h. The resulting mixture was concentrated at 30 °C. The residue was dissolved in EtOAc and H_2O. The organic phase was separated, washed with saturated aqueous $NaHCO_3$ and brine, and dried (Na_2SO_4). Concentration followed by silica gel column chromatography (EtOAc/hexane, 1:3 and 1:1) gave *syn* product **30** (17.1 g, 0.039 mol, 100%) as a colorless oil: $[\alpha]^{20}_D$ +81 (*c* 0.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 1.87 (1H, m, H-3a of hexenoyl), 2.00−2.09 (3H, m, H-3b and H_2-4 of hexenoyl), 2.61−2.64 (1H, overlapped, $PhCH_{2a}$), 2.61 (1H, d, J = 2.9 Hz, OH), 3.23 (1H, d, J = 13.2 Hz, $PhCH_{2b}$), 3.71 (1H, dd, J = 8.8, 8.8 Hz, H-5a), 3.80 (3H, s, OCH_3), 3.84 (3H, s, OCH_3), 3.97 (1H, d, J = 8.8 Hz, H-5b), 4.28−4.38 (2H, m, 2-H of hexenoyl, H-4), 4.78 (1H, br s, ArC*H*OH), 4.91−5.00 (2H, m, H_2-6 of hexenoyl), 5.74 (1H, m, H-5 of hexenoyl), 6.75 (1H, d, J = 8.3 Hz, ArH), 6.84 (1H, d, J = 8.3 Hz, ArH), 6.95 (1H, s, ArH), 7.14−7.16 (2H, m, ArH), 7.21−7.30 (3H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 27.2, 31.7, 37.9, 49.9, 55.7, 55.8, 55.9, 65.9, 75.1, 109.3, 110.7, 115.2, 118.5, 127.3, 128.9, 129.3, 134.2, 135.2, 137.9, 148.5, 148.8, 153.1, 174.8; *anal*. C 68.10%, H 6.57%, N 3.00%, calcd for $C_{25}H_{29}O_6N$, C 68.32%, H 6.65%, N 3.19%.

(2*S*,3*S*,5*R*)-5-[(*S*)-(Hydroxy)(3,4-dimethoxyphenyl)methyl]-3-(3,4-dimethoxycinnamyl)-2-(3,4-dimethoxyphenyl)tetrahydropyran [(−)-7′,8′-*erythro*-morinol A] (31): colorless oil; $[\alpha]^{20}_D$ −28 (*c* 0.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.87 (1H, m, H-4a (H-9a)), 1.78−1.88 (2H, m, H-3 (H-8), H-4b (H-9b)), 2.03 (1H, m, $ArCH{=}CHCH_{2a}$ (H-9″a)), 2.05 (1H, m, H-5 (H-8′)), 2.38 (1H, m, $ArCH{=}CHCH_{2b}$ (H-9″b)), 3.28 (1H, dd, J = 11.4, 11.4 Hz, H-6a (H-9′a)), 3.84−3.89 (2H, overlapped, H-2, H-6b (H-9′b)), 3.85 (3H, s, OCH_3), 3.86 (3H, s, OCH_3), 3.864 (3H, s, OCH_3), 3.870 (3H, s, OCH_3), 3.88 (6H, s, OCH_3), 4.38 (1H, d, J = 7.3 Hz, ArC*H*OH (H-7′)), 5.85 (1H, m, $ArCH{=}CHCH_2$ (H-8″)), 6.17 (1H, d, J = 15.7 Hz, $ArCH{=}CHCH_2$ (H-7″)), 6.77−6.89 (9H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 32.7, 35.9, 41.8, 43.6, 70.7, 76.1, 85.6, 108.6, 109.2, 110.4, 110.8, 110.9, 111.0, 111.2, 118.6, 118.9, 120.2, 125.8, 130.8, 131.3, 133.5, 135.3, 148.4, 148.9, 149.05, 149.1, 149.3; HREIMS *m*/*z* 564.2725 (calcd for $C_{25}H_{32}O_6$, 564.2724).

(2*R*,3*R*,5*R*)-5-[(*S*)-(Hydroxy)(3,4-dimethoxyphenyl)methyl]-3-(3,4-dimethoxycinnamyl)-2-(3,4-dimethoxyphenyl)tetrahydropyran [(+)-7′,8′-*erythro*-morinol B] (32): colorless oil; $[\alpha]^{20}_D$ +34 (*c* 0.4, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 1.51 (1H, m, H-4a (H-9a)), 1.80−1.92 (2H, m, H-3 (H-8), H-4b (H-9b)), 2.07 (1H, m, $ArCH{=}CHCH2a$ (H-9″a)), 2.28 (1H, m, $ArCH{=}CHCH_{2b}$ (H-9″b)), 2.42 (1H, s, OH), 2.45 (1H, m, 5-H (H-8′)), 3.64 (1H, dd, J = 9.1, 1.9 Hz, H-6a (H-9′a)), 3.86−3.92 (1H, overlapped, H-6b (H-9′b)), 3.856 (6H, s, OCH_3), 3.861 (3H, s, OCH_3), 3.87 (3H, s, OCH_3), 3.88 (3H, s, OCH_3), 3.92 (3H, s, OCH_3), 3.99 (1H, d, J = 10.1 Hz, H-2, (H-7)), 5.11 (1H, d, J = 8.5 Hz, ArCHOH (H-7′)), 5.87 (1H, m, $ArCH{=}CHCH_2$ (H-8″)), 6.19 (1H, d, J = 15.7 Hz, $ArCH{=}CHCH_2$ (H-7″)), 6.79−6.83 (2H, m, ArH), 6.88 (1H, d, J = 8.2 Hz, ArH), 6.92−6.97 (3H, m, ArH); ^{13}C NMR ($CDCl_3$) δ 30.0, 36.0, 37.7, 41.5, 55.75, 55.82, 55.87, 55.90, 70.3, 74.8, 86.1, 108.5, 109.2, 110.7, 110.8, 111.1, 118.8, 119.1, 120.0, 125.6, 130.7, 131.2, 133.5, 136.0, 148.3, 148.5, 148.87, 148.94, 149.0, 149.1; HREIMS *m*/*z* 564.2726 ($C_{25}H_{32}O_6$ requires, 564.2724).

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