A Formal Synthesis of (+)-Cassiol Exploiting Meyers' Bicyclic Lactam Methodology†

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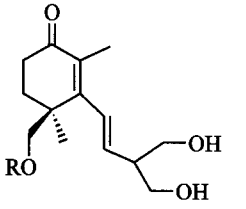
A formal synthesis of (+)-cassiol using (1*S*,2*S*)-2-amino-1-(4-nitrophenyl)-1,3-propanediol as chiral auxiliary is reported. The quaternary chiral center in the molecule was constructed by sequential alkylation of a bicyclic lactam (prepared from the aforementioned auxiliary and 5-oxo-heptanoic acid) with methyl iodide and benzyloxymethyl chloride.

Keywords bicyclic lactam, asymmetric alkylation, chiral quaternary carbon

Introduction

In 1988, from an aqueous extraction of Chinese cinnamon, which has long been used in the traditional Chinese medicine as a diaphoretic, antipyretic, or analgesic agent, Fukaya and co-workers isolated cassioside (**1**) and found that this compound possessed remarkable antiulcerogenic activity. Enzymatic hydrolysis of **1** with *β-D*-glucosidase afforded (+)-cassiol (**2**), which showed even stronger antiulcerogenic effect than that of cassioside itself.[1] Due to its interesting structural motif, compound **2** has been serving as a "testing ground" for chemists to examine various synthetic methodologies over the last decade.[2] (Fig. 1).

Since 1980's Meyers[3] and co-workers have been using bicyclic lactams derived from chiral amino alcohols to construct chiral quaternary carbons. One of the advantages of Meyers' methodology is that the configuration of the newly formed chiral center can be pre-determined with very high confidence through adjusting the alkylation sequence, because the face-preferential entry of the alkylating agent in such bicyclic lactams is efficiently controlled by the chirality of the starting auxiliary. Apparently, this attractive feature may find application in the synthesis of the quaternary center in cassiol. Disclosed below (Fig. 1) is a route to (+)-**2** based on such bicyclic lactam methodology.



1 R = *β*-glucopyranosyl
2 R = H

Fig. 1 Structures of componnds **1** and **2**.

Results and discussion

In the outset we envisioned that the quaternary chiral carbon in **2** could be constructed via the bicyclic lactam methodology introduced by Meyers. Taber[2e] and co-workers have developed a successful synthetic route to elabo-

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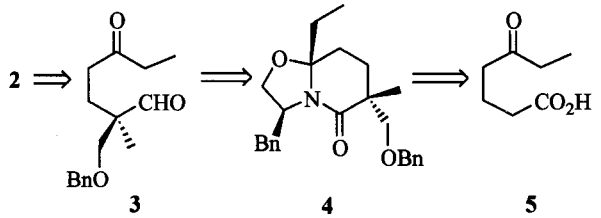
†Dedicated to Professor HUANG Yao-Zeng on the occasion of his 90th birthday.

rate the dicarbonyl compound **3** into **2**. Therefore, the primary target of this endeavor was set to ketone-aldehyde **3**. The retrosynthetic analysis is shown in Scheme 1. It was anticipated that sequential alkylation of the bicyclic lactam prepared from 5-oxoheptanoic acid and (*S*)-2-amino-3-phenyl-1-propanol, a well-documented[3] chiral auxiliary, would generate the desired quaternary carbon with pre-defined configuration. Partial reduction of the dialkylated lactam (**4**) followed by hydrolysis would provide a quick access to the chiral ketone-aldehyde **3**.

Scheme 1

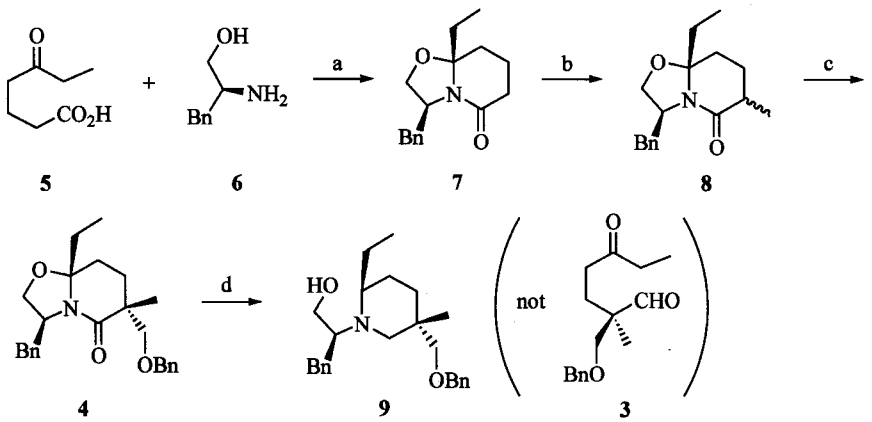


A synthetic sequence (Scheme 2) was then designed according to the above retrosynthetic analysis. The acid **5** was prepared (73.9% yield) by reaction of glutaric anhydride with diethylcadmium following the procedure[4] described by Levine. Treatment of **5** with equal molar (*S*)-2-amino-3-phenyl-1-propanol gave the desired bicyclic lactam (**7**) in 82.9% yield. Subsequent deprotonation of **7** using lithium diisopropylamide (LDA) followed by exposure to an excess of MeI afforded monomethylated product **8** in 72% yield as a mixture of *endo*/*exo* isomers, along with 13.2% of dimethylated one. The *endo*/*exo* isomers were used as such in the second deprotonation to yield a single cabanion, which on reaction with $BnOCH_2Cl$[5] produced dialkylated bicyclic lactam **4** in 63.6% yield. The clean ^1H and ^{13}C NMR spectra of **4** suggested that the newly formed quaternary chiral carbon had a uniform configuration.

Up to this point it appeared that the target **3** was already in sight. However, the next reduction with Red-Al (sodium bis(2-methoxyethoxy)aluminum hydride, the most successful reagent[3] for such a purpose) led to ring cleavage product **9** in quantitative yield (Scheme 3), instead of the anticipated partial reduction of the lactam carbonyl. In order to circumvent the undesired cleavage reaction, we next decided to turn to some more complicated chiral auxiliaries that carry an additional carbinol moiety, because such a structural feature appeared to facilitate partial reduction of the lactam carbonyl as manifested by several literature cases.

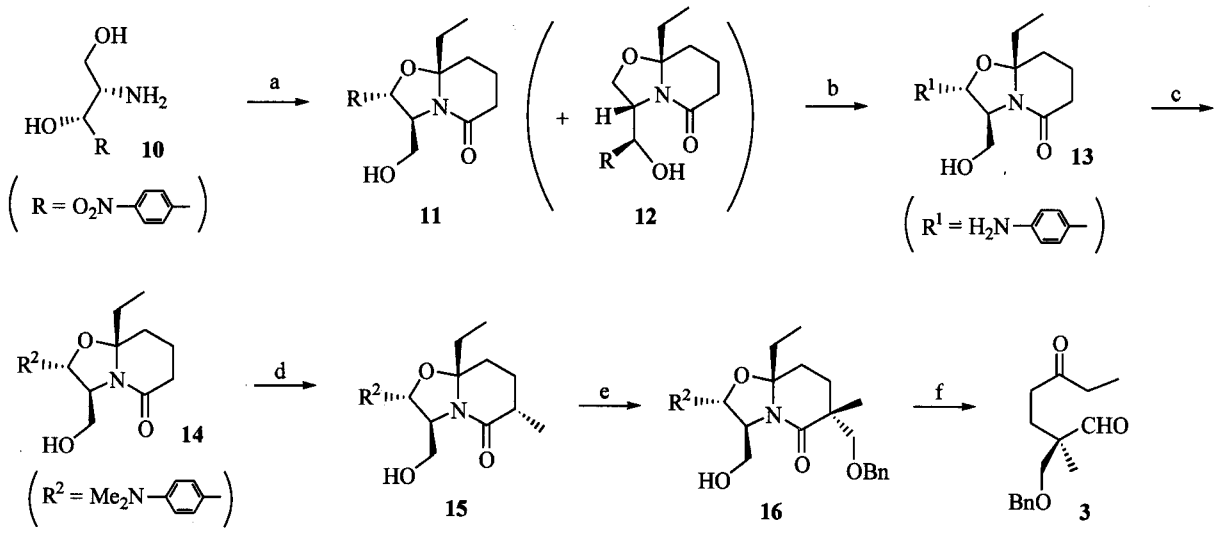
Among various amino alcohols that might suit our purpose, compound **10** seemed to be a good candidate——it is a useless by-product (undesired enantiomer in the industrial optical resolution) in the manufacture of antibiotic chloramphenical and therefore very cheap. A new route based on this auxiliary (Scheme 3) was then designed. Unlike the clear-cut formation of **7** from **5** and **6** in the previous route, the presence of an additional carbinol in the molecule did cause some problem. Apart from the desired lactam **11** (73% yield), another isomer **12** was also formed (13.4% yield). To avoid interference of the strong electron-withdrawing substituent NO_2 on the phenyl ring, a reduction of the nitro group was performed

Scheme 2



Reagents and conditions: (a) toluene/reflux, 82.9%; (b) LDA/MeI, 72.0%; (c) LDA/$BnOCH_2Cl$, 63.6%; (d) Red-Al/THF, 100%.

Scheme 3



Reagents and conditions: (a) **5**/benzene/reflux, total yield 86.4%; (b) $Na_2S \cdot 9H_2O$/EtOH/60 ℃, 77.7%; (c) $NaBH_4/H_2SO_4$/HCHO/THF, 92.6%; (d) LDA/MeI, 82.1%; (e) LDA/HMPA/$BnOCH_2Cl$, 49.7%; (f) Red-Al/rt, then $Bu_4NH_2PO_4$/EtOH/H_2O/rt, yield 10.6% over two steps.

first. Thus, by treatment[6] with $Na_2S \cdot 9H_2O$ in EtOH at 60 ℃, the *p*-NO_2 group was converted to an amino group (NH_2) in 77.7% yield. Methylation of the newly formed amino group with MeI in the presence of K_2CO_3 did not proceed so well. Apart from the desired dimethylated amino species, some monomethylated and quaternary ammonium salts were also present in the product mixture. Changing the reaction conditions did not help to improve the yield of the dimethylated amine. Switching to HCHO/HCO_2H[7] at reflux did not result in any improvement, either (no desired product could be detected). Finally, the dimethylamino species was successfully prepared using $NaBH_4$/HCHO[8] in the presence of H_2SO_4. Under this set of methylation conditions, **14** was readily obtained in 92.6% yield.

Further deprotonation of **14** with LDA as described above for **7** and carbon-methylation with MeI gave only one isomer **15** in 82.1% yield, which was in sharp contrast to the situation with **7** (where both *endo* and *exo* isomer were formed). Benzyoxymethylation with $BnOCH_2Cl$ under the same conditions employed in preparation of **4** afforded **16** in moderate yield. With an extra (compared with **4**) hydroxymethyl in the close vicinity, partial reduction of the lactam carbonyl was significantly improved (starting material was fully consumed within 24 h). After hydrolysis with $Bu_4NH_2PO_4$, some products stemming from the reduction were indeed observed. The desired aldehyde **3**, an advanced intermediate[2e] in Taber's synthesis of (+)-cassiol, was thus finally obtained in pure form (10.6% after column chromatography).

Experimental

^1H NMR and ^{13}C NMR spectra were recorded on an AMX-300 spectrometer (operating at 300 MHz for observing ^1H) with $CDCl_3$ as solvent and Me_4Si as internal reference. Mass sepctra were taken on an HP 5989A instrument. HRMS (EI) spectra were obtained on a Finnigan Mat 8430 mass spectrometer. Optical rotations were measured on a Perkin-Elmer 241 MC polarimeter. IR spectra were recorded on a Shimadzu IR-440 spectrometer. Flash column chromatography was performed on silica gel H (10—40 μm), eluting with a mixture of ethyl acetate (EA)/petroleum ether (PE) (*V*/*V*) of a proper ratio. Microanalyses were carried out in the Microanalytical Laboratory at Shanghai Institute of Organic Chemistry.

Bicyclic lactam (+)-**7**

A stirred solution of 5-oxo-hexanoic acid (**5**, 1.173 g, 8.1 mmol) and (*S*)-amino-alchol (**6**, 1.23 g, 8.1 mmol) was heated at reflux in toluene (65 mL) for 24 h with concurrent azeotropic removal of the water formed in

the reaction through a Dean-Stark trap. The solution was then concentrated under reduce pressure. The residue was purified by flash chromatography (EA:PE = 1:5) to yield bicyclic lactam **7** as a yellowish liquid (1.750 g, 82.9% yield). $[\alpha]_D^{21}$ + 6.43 (*c* 2.96, $CHCl_3$); ^1H NMR δ: 7.35—7.15 (m, 5H), 4.43—4.36 (m, 1H), 3.96 (dd, *J* = 7.9, 9.16 Hz, 1H), 3.75 (t, *J* = 8.7 Hz, 1H), 3.51 (dt, *J* = 3.4, 13.2 Hz, 1H), 2.73—2.65 (m, 1H), 2.62—2.46 (m, 2H), 2.26 (dt, *J* = 7.2, 3.6 Hz, 1H), 1.92—1.86 (m, 1H), 1.77—1.66 (m, 1H), 1.61—1.50 (m, 2H), 1.37 (dt, *J* = 4.3, 13.2 Hz, 1H), 0.88 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR: (75 MHz, $CDCl_3$) δ: 169.37, 137.52, 129.08, 128.39, 126.46, 95.39, 67.26, 56.71, 39.76, 30.31, 29.93, 27.50, 16.39, 8.15; IR (film) ν: 2930, 2850, 1675, 1640, 1400, 1050, 980, 940 cm^{-1}; EIMS *m/z* (%): 260 (M^+ + 1, 71), 230 (M^+ - Et, 64), 169 (11), 168 (100), 117 (23), 91 (21), 84 (9), 55 (10); HRMS calcd for $C_{16}H_{21}NO_2$ 259.1572, found 259.1559.

Dialkylated bicyclic lactam (+)-**4**

With stirring and cooling (-78 ℃ bath), *n*-BuLi (2.5 mol/L, 8 mL, 20 mmol) was added to a solution of dry *i*-Pr_2NH (2.7 mL) in dry THF (100 mL) under N_2. The solution was allowed to warm naturally to 0 ℃ to ensure complete deprotonation. The reaction mixture was re-cooled to -78 ℃ before bicyclic lactam **7** (2.59 g, 10.0 mmol) in THF (15 mL) was added. The bath temperature was then allowed to warm to 0 ℃ to facilitate deprotonation of **7**. After that, the mixture was re-cooled to -78 ℃ before MeI (1.87 mL) was added. Stirring was continued at -78 ℃ for 3 h. The reaction was quenched with aqueous HCl (6 mol/L). The mixture was concentrated on a rotary evaporator and the residue was dissolved in ethyl acetate (100 mL), washed with water, brine, dried over $MgSO_4$, and purified by flash chromatography (EA:PE = 1:3) to yield the monomethylated lactam **8** in 72.0% yield as a mixture of the *endo/exo* isomers.

The mixture of *endo/exo* isomers was then subjected to the same deprotonation-alkylation sequence as just described above except for that the MeI was replaced by $BnOCH_2Cl$. Compound **4** yielded as a white solid (63.6% yield). M.p. 94—96 ℃; $[\alpha]_D^{21}$ + 22.4 (*c* 2.00, $CHCl_3$); ^1H NMR δ: 7.30—7.19 (m, 10H), 4.54 (d, *J* = 12.1 Hz, 1H), 4.42 (d, *J* = 12.4 Hz, 1H), 3.93 (t, *J* = 8.0 Hz, 1H), 3.80 (d, *J* = 8.2 Hz, 1H), 3.73 (t, *J* = 8.8 Hz, 1H), 3.43 (dd, *J* = 3.2, 13.0 Hz, 1H), 3.31 (d, *J* = 8.5 Hz, 1H), 2.72 (dd, *J* = 10.0, 13.0 Hz, 1H), 2.11—2.07 (m, 2H), 1.70 (dt, *J* = 5.0, 13.7 Hz, 1H), 1.58—1.50 (m, 4H), 1.20 (s, 3H), 0.84 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR δ: 173.08, 138.04, 137.22, 128.86, 127.99, 127.78, 126.87, 126.09, 95.18, 76.97, 76.54, 76.12, 72.90, 67.24, 56.53, 42.00, 39.09, 28.47, 28.13, 26.72, 24.32, 7.83; IR (KBr) ν: 2990, 1645, 1460, 1420, 1095, 1040, 900, 760 cm^{-1}; EIMS *m/z* (%): 394 (M^+ + 1, 9), 393 (M^+, 30), 364 (M^+ - Et, 24), 363 (84), 301 (60), 196 (15), 117 (10), 91 (100); HRMS calcd for $C_{23}H_{26}NO_3$ (M^+ - Et) 364.1912, found 364.1903.

Bicyclic lactams (+)-**11** *and* (+)-**12**

The procedure was the same as described above for preparing **7**. The yield of (+)-**11** was 73.0% and that of (+)-**12** was 13.4%.

11 M.p. 109.5—110.5 ℃; $[\alpha]_D^{27}$ + 12.5 (*c* 0.98, $CHCl_3$); ^1H NMR δ: 8.24 (d, *J* = 8.5 Hz, 2H), 7.60 (d, *J* = 8.8 Hz, 2H), 4.85 (d, *J* = 8.2 Hz, 1H), 4.00 (dt, *J* = 2.8, 8.2 Hz, 1H), 3.92 (dd, *J* = 3.0, 11.3 Hz, 1H), 3.82 (dd, *J* = 8.0, 11.3 Hz, 1H), 2.57 (ddd, *J* = 2.47, 7.42, 18.9 Hz, 1H), 2.48—2.39 (m, 2H), 2.04—1.88 (m, 2H), 1.84—1.74 (m, 2H), 1.69—1.58 (m, 1H), 0.97 (t, *J* = 7.4 Hz, 3H); IR (KBr) ν: 3401, 2974, 1623, 1561, 1404, 1351, 1081, 1048 cm^{-1}; EIMS *m/z* (%): 321 (M^+ + 1, 100), 292 (17), 291 (92), 273 (15), 261 (36), 227 (24), 55 (31), 41 (12). Anal. calcd for $C_{16}H_{20}N_2O_5$: C 59.99, H 6.29, N 8.74; found C 60.22, H 6.20, N 8.68.

12 M.p. 132.5—133.5 ℃; $[\alpha]_D^{27}$ + 19.4 (*c* 2.39, $CHCl_3$); ^1H NMR δ: 8.23 (d, *J* = 8.8 Hz, 2H), 7.61 (d, *J* = 8.8 Hz, 2H), 4.70 (d, *J* = 9.1 Hz, 1H), 4.37 (q, *J* = 8.8 Hz, 1H), 3.57 (dd, *J* = 8.4, 9.8 Hz, 1H), 3.49 (t, *J* = 9.3 Hz, 1H), 2.66—2.58 (m, 1H), 2.48 (dd, *J* = 7.8, 10.0 Hz, 1H), 2.32 (dt, *J* = 13.2, 3.8 Hz, 1H), 1.99—1.91 (m, 1H), 1.85—1.75 (m, 3H), 1.46 (dt, *J* = 13.2, 4.4 Hz, 1H), 0.95 (t, *J* = 7.4 Hz, 3H); IR (KBr) ν: 3230, 2970, 1708, 1618, 1527, 1438, 1404, 1351 cm^{-1}; EIMS *m/z* (%): 321 (M^+ + 1, 14), 303 (16), 169 (17), 168 (100), 84 (18), 55 (29), 42 (9), 41 (9). Anal. calcd for $C_{16}H_{20}N_2O_5$: C 59.99, H

6.29, N 8.74; found C 59.96, H 6.36, N 8.75.

Bicyclic lactam **13**

To a solution of **11** (5.00 g, 15.6 mmol) in absolute ethanol (150 mL) stirred at 60 ℃, $Na_2S \cdot 9H_2O$ (10.5 g, 43.8 mmol) was added. The reaction mixture was stirred for 1 h and cooled to the ambient temperature. After removing the solvent on a rotary evaporator, the residue was extracted with boiling ethyl acetate (100 mL × 4). The combined ethyl acetate extracts were dried over $MgSO_4$. Removal of the solvent and drying agent followed by column chromatography (EA : PE = 4 : 1) gave compound **13** as white solid (3.52 g, 77.7% yield). M.p. 154—155 ℃; $[\alpha]_D^{27}$ + 6.88 (*c* 0.93, $CHCl_3$); ^{1}H NMR δ: 7.16 (d, *J* = 8.2 Hz, 2H), 6.66 (d, *J* = 8.8 Hz, 2H), 4.56 (d, *J* = 8.8 Hz, 1H), 4.02 (dt, *J* = 2.0, 8.7 Hz, 1H), 3.81 (dd, *J* = 2.2, 11.3 Hz, 1H), 3.69 (dd, *J* = 8.5, 11.3 Hz, 1H), 2.52 (dd, *J* = 2.8, 7.7 Hz, 1H), 2.47—2.44 (m, 1H), 2.37 (dt, *J* = 12.9, 3.7 Hz, 1H), 1.98—1.88 (m, 2H), 1.71 (dd, *J* = 7.4, 14.6 Hz, 2H), 1.58 (ddt, *J* = 1.7, 4.4, 13.3 Hz, 1H), 0.94 (t, *J* = 7.4 Hz, 3H); IR (KBr) ν: 3433, 3352, 3238, 2920, 1612, 1523, 1442, 1409 cm^{-1}; EIMS *m/z* (%): 290 (M^+, 5), 243 (100), 147 (29), 130 (41), 126 (40), 110 (26), 106 (31), 55 (37). Anal. calcd for $C_{16}H_{22}N_2O_3$: C 66.18, H 7.64, N 9.65; found C 66.11, H 7.64, N 9.45.

Bicyclic lactam **14**

A slurry of compound **13** (760 mg, 2.62 mmol) and finely crushed $NaBH_4$ (697 mg, 18.4 mmol) in THF (20 mL) was added to a mixture of H_2SO_4 (3 mol/L, 2.2 mL, 6.6 mmol) and aqueous formaldehyde (37%, 1.2 mL) stirred in a 50-mL flask at such a rate that the internal temperature did not exceed 20 ℃. After the addition was complete, the mixture was made strongly basic with solid NaOH. The supernatant solution was decanted and saved. The residue was treated with water (15 mL) and then extracted with CH_2Cl_2 (15 mL × 4). The combined organic extracts and the supernatant were dried over $MgSO_4$. Flash chromatography (EA : PE = 2 : 1) afforded compound **14** as white solid (772 mg, 92.6% yield). M.p. 130—131 ℃; $[\alpha]_D^{27}$ + 2.79 (*c* 1.30, $CHCl_3$); ^{1}H NMR δ: 7.24 (d, *J* = 8.5 Hz, 2H), 6.72 (d, *J* = 8.5 Hz, 2H), 5.24 (d, *J* = 6.9 Hz, 1H), 4.58 (d, *J* = 8.8 Hz, 1H), 4.06 (t, *J* = 8.5 Hz, 1H), 3.84—3.79 (m, 1H), 3.70 (dd, *J* = 8.8, 11.0 Hz, 1H), 2.95 (s, 6H), 2.52 (dt, *J* = 12.6, 3.6 Hz, 1H), 1.99—1.87 (m, 2H), 1.77—1.57 (m, 3H), 0.94 (t, *J* = 7.4 Hz, 3H); IR (KBr) ν: 3298, 2893, 1610, 1527, 1444, 1405, 1347, 1194 cm^{-1}; EIMS *m/z* (%): 318 (M^+, 44), 271 (80), 162 (19), 158 (36), 134 (19), 126 (100), 110 (50), 55 (30). Anal. calcd for $C_{18}H_{26}N_2O_3$: C 67.90, H 8.23, N 8.80; found C 67.82, H 8.29, N 8.67.

Bicyclic lactam **15**

The procedure was the same as described above for preparing **8**. The yield of methylated lactam **15** was 82.1%. M.p. 79.5—80.5 ℃; $[\alpha]_D^{25}$ + 7.22 (*c* 1.06, $CHCl_3$); ^{1}H NMR δ: 7.21 (d, *J* = 8.8 Hz, 2H), 6.69 (d, *J* = 8.8 Hz, 2H), 5.15 (d, *J* = 7.2 Hz, 1H), 4.56 (d, *J* = 8.8 Hz, 1H), 4.02 (dt, *J* = 1.7, 10.2 Hz, 1H), 3.77 (d, *J* = 5.8 Hz, 1H), 3.67 (dd, *J* = 8.7, 10.8 Hz, 1H), 2.89 (s, 6H), 2.48 (dd, *J* = 7.1, 12.4 Hz, 1H), 2.20 (dt, *J* = 12.9, 5.0 Hz, 1H), 2.03—1.86 (m, 2H), 1.78—1.56 (m, 3H), 1.27 (d, *J* = 7.2 Hz, 3H), 0.93 (t, *J* = 7.4 Hz, 3H); IR (KBr) ν: 3323, 2968, 2938, 2884, 1608, 1526, 1464, 1429 cm^{-1}; EIMS *m/z* (%): 33 (M^+ + 1, 23), 332 (M^+, 45), 285 (86), 158 (45), 140 (100), 134 (22), 124 (31), 55 (28). Anal. calcd for $C_{19}H_{28}N_2O_3$: C 68.65, H 8.49, N 8.43; found C 68.76, H 8.54, N 8.42.

Bicyclic lactam **16**

The procedure was the same as described above for preparing **4**. The yield of compound **16** was 49.7%. $[\alpha]_D^{25}$ + 32.9 (*c* 1.39, $CHCl_3$); ^{1}H NMR δ: 7.35—7.31 (m, 5H), 7.15 (d, *J* = 8.4 Hz, 2H), 6.67 (d, *J* = 8.1 Hz, 2H), 5.27 (brs, 1H), 4.57—4.46 (m, 3H), 4.07 (dt, *J* = 2.1, 8.5 Hz, 1H), 3.86 (d, *J* = 8.4 Hz, 1H), 3.79 (s, 1H), 3.74—3.67 (m, 1H), 3.39 (d, *J* = 8.1 Hz, 1H), 2.94 (s, 6H), 2.24—2.10 (m, 3H), 1.96—1.89 (m, 1H), 1.75—1.66 (m, 2H), 1.21 (s, 3H), 0.93 (t, *J* = 7.5 Hz, 3H); IR (film) ν: 3339, 2970, 2935, 2875, 1616, 1527, 1457, 1426 cm^{-1}; EIMS *m/z* (%): 453 (M^+ + 1, 23), 452 (M^+, 36), 406 (23), 405 (76), 314 (23),

260 (27), 134 (24), 91 (100). Anal. calcd for $C_{27}H_{36}N_2O_4$: C 71.65, H 8.02, N 6.19; found C 71.36, H 7.84, N 6.04.

Preparation[9] *of* $Bu_4NH_2PO_4$

Commercially available aqueous Bu_4NOH was added to a solution of H_2PO_4 (2 mL) in water (20 mL) until the pH = 5. Water was removed on a rotary evaporator. $CHCl_3$ was added to the residue (to dissolve $Bu_4NH_2PO_4$). Insoluble materials were filtered off and the filtrate was evaporated to dryness. Recrystallization from THF gave $Bu_4NH_2PO_4$ (9.0 g, 73.2% yield). (*cf.* the original procedure[9] given in French).

(2*S*)-2-*Methyl*-5-*oxo*-2-*phenzyloxymethyl*-*heptanal* (**3**)

Red-Al (65 wt%, 1.0 mL) was added to a solution of compound **16** (220 mg, 0.63 mmol) in anhydrous THF (10 mL). The mixture was stirred for 24 h. Methanol (2 mL) was added at 0 ℃ to quench the reaction. After removal of the solvent by rotary evaporation, aqueous ethanol (50%, 6 mL) and $Bu_4NH_2PO_4$ (1.10 g) were added. The mixture was stirred at the ambient temperature for 7 d. The unstable dicarbonyl compound **3** was obtained after column chromatography (EA : PE = 1 : 10) as a colorless oil (10.6% yield over two steps; some of **3** might be lost due to undesired reactions occurred on the silica gel column). $[\alpha]_D^{25}$ −1.63 (*c* 1.45, CH_2Cl_2); ^{1}H NMR δ: 9.50 (s, 1H), 7.31—7.25 (m, 5H), 4.47 (s, 2H), 3.45 (q, J = 9.1 Hz, 2H), 2.36 (q, J = 7.4 Hz, 2H), 2.32 (t, J = 8.1 Hz, 2H), 1.89 (dt, J = 14.3, 7.69 Hz, 1H), 1.75 (dt, J = 14.6, 7.69 Hz, 1H), 1.05 (s, 3H), 1.01 (t, J = 7.4 Hz, 3H); IR (film) ν: 2950, 2850, 1725, 1715, 1457, 1100, 740, 700 cm^{-1}; EIMS *m/z* (%): 261 (M^+ − 1, 23), 181 (9), 155 (14), 97 (7), 92 (11), 91 (100), 65 (10), 57 (30).

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