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Total Synthesis of Lathyranoic Acid A

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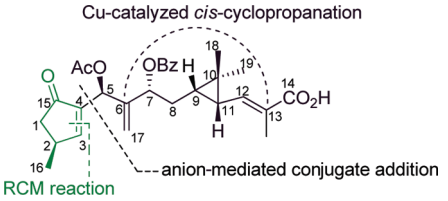

The first total synthesis of lathyranoic acid A (**1**) was accomplished stereoselectively in a linear sequence of 20 steps and an overall yield of 1.4%. This modular synthesis featured a cyclic, stereocontrolled Cu-catalyzed intramolecular cyclopropanation to construct the *cis*-cyclopropane unit, a Grubbs metathesis to construct the γ-substituted cyclopentenone moiety, and an anion-mediated conjugate addition.

Lathyranoic acid A (**1**) was first isolated in 2005[1] from the seeds of *Euphorbia lathyris*, a common traditional Chinese medicine used for the treatment of hydropsy, ascites, scabies, and snakebites.[2] To date, a series of diterpenoids from species in the *Euphorbiaceae* family have been reported to show many important biological effects, including the activation of protein kinase C,[3] anticancer,[4] and anti-HIV activity[5] as well as P-glycoprotein inhibition.[6] Among these diterpenoids, lathyranoic acid A is a secolathyrane diterpenoid with an unprecedented skeleton, originally proposed as an oxidation product of *Euphorbia* factor L_{11} isolated from the seeds of *E. lathyris*.[1] Lathyranoic acid A possesses a unique stereochemical distribution, including a stereodefined *cis*-vinylcyclopropane and a 2-methylene-1,3-alkoxide. These interesting moieties combined with the potential biological activity drew our attention; we elected to synthesize and generate its analogues for further biological examinations.

Our retrosynthetic analysis of lathyranoic acid A was outlined in **Figure 1**.[7] The skeleton could presumably be accomplished by an appropriate addition of alkenyllithium fragment **2** to the highly functionalized aldehyde **3**. The cyclopentenone moiety was constructed using an intramolecular ring-closing metathesis reaction of **4**, while the well-defined stereochemistry was generated via a methyllithium *syn* conjugate addition of enoate **6**. The framework of the aldehyde **3** could be constructed from lactone **5**, which could be formed in turn from a Cu-catalyzed intramolecular cyclopropanation of diazoacetate **7**.

Propargyl alcohol was advanced to the chiral 1,2-diol **8** following the reported procedure in four steps.[8] The primary hydroxy group was selectively protected with TBS to give **9**, which was then transformed to **10** by using glyoxylic acid chloride *p*-toluenesulfonyl hydrazone.[9] Copper-catalyzed intramolecular cyclopropanation of diazoacetate **10** afforded the *exo* intermediate bicyclic lactone **11** in 42% yield as a single product.[10] Unfortunately, the configuration of the *cis*-cyclopropane unit in **11** was found to be opposite to that of the natural product as seen from the single-crystal X-ray analysis of 4-bromobenzoate **12**, which was obtained through a two-step functional transformation of **11**.

The *exo* product was expected to be favored thermodynamically more than the *endo* isomer.[10] To get the correct *exo* product we turned our attention to the inverted secondary hydroxy **13**, which was obtained through a configuration inversion of **9** in two steps. Under similar conditions as used for **11**, compound **13** was converted into the *exo* bicyclic lactone **5** as a main product (**5**:**14** = 2.6:1). It is worth mentioning that the *cis*-cyclopropane was constructed in a cyclic stereocontrolled manner without the use of chiral catalyst. The absolute configuration of **5** was confirmed by the crystal structure of the deprotected derivative **15** (Scheme 1).

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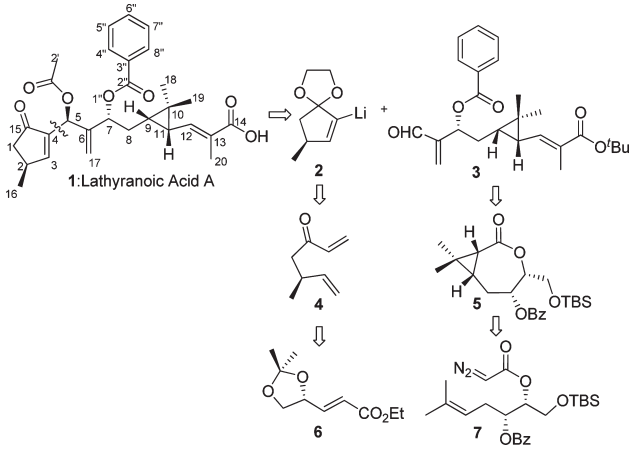
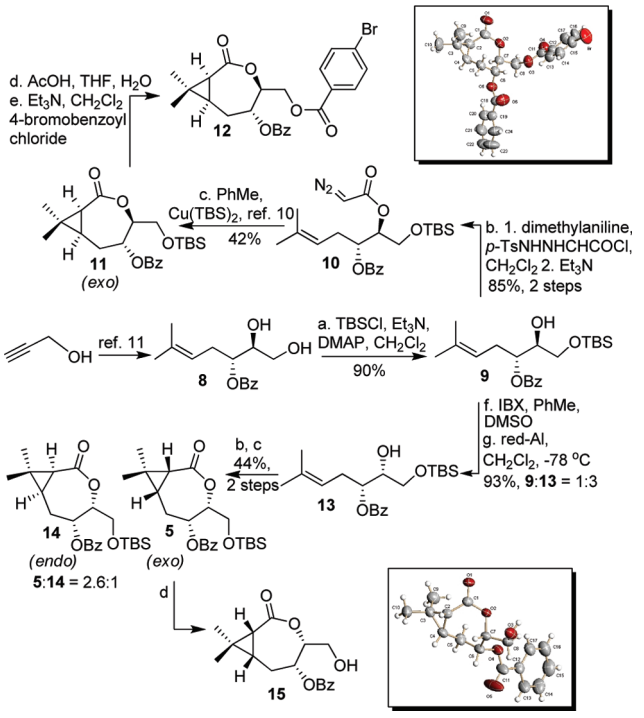


FIGURE 1. Retrosynthetic analysis of lathyranoic acid A.

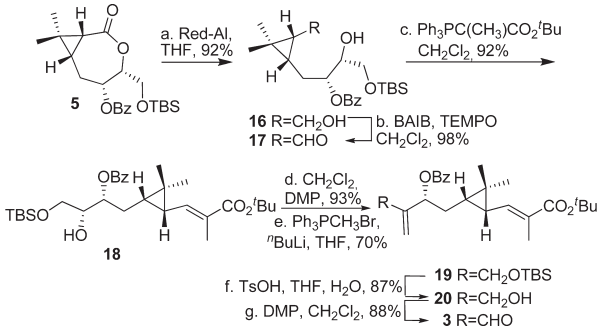
SCHEME 1. Preparation of Intermediate 5



With the desired lactone **5** in hand, we intended to selectively transform it to the corresponding aldehyde **17**. A wide variety of reaction conditions were screened but were invariably plagued by the simultaneous reduction of the benzoyl group. A selection of the methods tried included DIBAL-H/THF, DIBAL-H/PhMe, $NaBH_4$/MeOH, $NaBH_4$/EtOH/CH_2Cl_2, and red-Al/THF at different temperatures. Only treatment with red-Al at a lower temperature realized the selective reduction of **5**. The highest yield (92%) was obtained in the temperature range of −78 to −40 °C. Subsequently, selective oxidation of primary alcohol to an aldehyde using BAIB ((diacetoxyiodo)benzene) in the presence of a catalytic amount of TEMPO (2,2,6,6-tetramethyl-1-piperidinyloxyl free radical) converted **16** into **17** (98%). Aldehyde **17** was reacted with Wittig reagent[11] to afford the *E*-ester **18**

(11) Shing, T. K. M.; Yang, J. *J. Org. Chem.* **1995**, *60*, 5785–5789.

SCHEME 2. Preparation of Fragment 3



(> 95:5 *E*/*Z* ratio). DMP (Dess-Martin periodinane) oxidation of the alcohol **18** (93%) followed by a Wittig methylenation yielded ene **19** in 70% yield. Removal of the TBS group under acidic condition in the presence of water, followed by DMP oxidation provided the fragment aldehyde **3** in a good yield (88%) (Scheme 2).

It was reported that the chiral cyclopentenone system could be constructed via intermolecular Pauson-Khand reaction.[12] Here we described a more robust approach, using Grubbs metathesis as a key step. The stereoselective preparation of (*S*)-(−)-4-methyl-2-cyclopentenone (**23**) began with the commercially available compound, L-ascorbic acid. Following a known method,[13] aldehyde **21** was obtained in a good yield. Wittig methylenation of **21** followed by Grignard vinylation via the Weinreb amide afforded diene **4**, which was treated by Grubbs II catalyst to provide the RCM product **23** in an acceptable isolated yield. Cyclopentenone **23** was converted to its protected bromide **24** by monobromination and acetal formation (Scheme 3).

With the desired precursors **24** and **3** in hand, we then turned our attention to the assembly of the skeleton of lathyranoic acid A. The acetal bromide **24** underwent lithium-halogen exchange, and the resulting lithio intermediate was treated with aldehyde **3** in THF containing 2 equiv of HMPA at −78 °C to give alcohols **25** and **26** in 75% yield (**25**:**26** = 2:3). After acetylation, deprotection of the acetal and *tert*-butyl protecting groups the final product **1** was obtained (Scheme 4). The ^1H and ^{13}C NMR spectra as well as the $[\alpha]_D$ value of the synthetic lathyranoic acid A were consistent with that of the natural product.[1]

In summary, the total synthesis of lathyranoic acid A was accomplished selectively in a linear sequence of 20 steps and an overall yield of 1.4% from easily accessible starting materials. Herein, we have reported a flexible and convergent synthetic route that could generate further natural product analogues of **1**. To date, we have prepared some analogues of lathyranoic acid A using this reported methodology and we expect to report this in the near future.

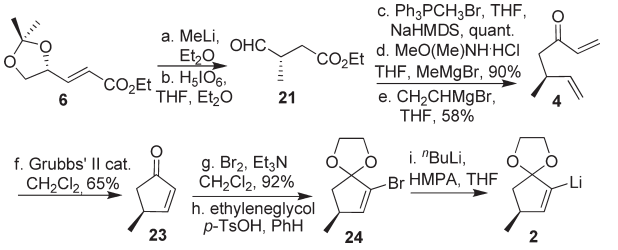
Experimental Section

(2*S*,3*R*)-1-(*tert*-Butyldimethylsilyloxy)-2-(2-diazoacetoxy)-6-methylhept-5-en-3-yl Benzoate (10). A suspension of glyoxylic acid *p*-toluenesulfonyl hydrazone (510 mg, 1.98 mmol) in a solution of

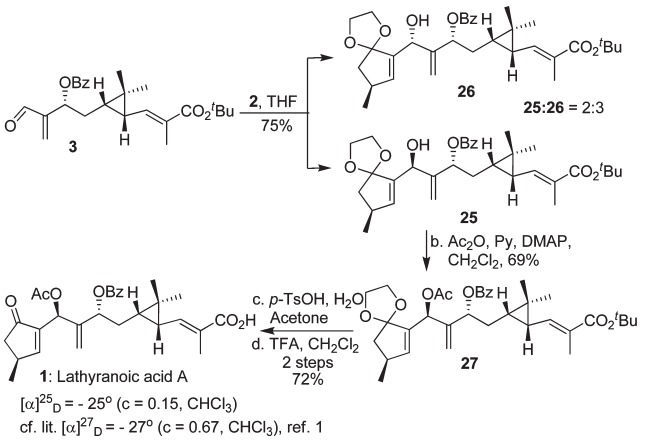
(12) Verdaguer, X.; Vazquez, J.; Fuster, G.; Bernard-Genisson, V.; Greene, A. E.; Moyano, A.; Pericas, M. A.; Riera, A. *J. Org. Chem.* **1998**, *63*, 7037–7052.

(13) Al Dulayymi, J. R.; Baird, M. S.; Roberts, E.; Deysel, M.; Verschoor, J. *Tetrahedron* **2007**, *63*, 2571–2592.

SCHEME 3. Synthesis of Cyclopropenane Moiety



SCHEME 4. Completion of the Synthesis of Lathyranoic Acid A



10 mL of anhydrous benzene and 1 mL of thionyl chloride was refluxed with stirring for 1.5 h under an argon atmosphere. The solvent was placed on a high-vacuum line for 1 h to remove residual thionyl chloride. This material was used immediately without purification. The crude glyoxylic acid chloride *p*-toluenesulfonyl hydrazone in 2 mL of CH_2Cl_2 was dropped into a solution of **9** (500 mg, 1.32 mmol) in 30 mL of anhydrous CH_2Cl_2 in an ice bath under an argon atmosphere. Dimethylaniline (235 μL, 1.85 mmol) was added with stirring for 15 min prior to addition of Et_3N (235 μL, 1.98 mmol). The resulting dark orange solution was stirred for 10 min at 0 °C and then 20 min at room temperature. The CH_2Cl_2 solution was evaporated. Flash column chromatography (PE:EtOAc = 40:1) provided **10** (500 mg) as a yellow oil in 85% yield. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.01 (d, 2H, J = 8.1 Hz), 7.56 (t, 1H, J = 7.2 Hz), 7.44 (t, 2H, J = 7.2 Hz), 5.41−5.36 (m, 1H), 5.28−5.23 (m, 1H), 5.15 (t, 1H, J = 6.6 Hz), 4.77 (s, 1H), 3.88 (dd, 1H, J = 11.1, 4.5 Hz), 3.80 (dd, 1H, J = 10.8, 6.0 Hz), 2.47 (t, 2H, J = 6.6 Hz), 1.65 (s, 3H), 1.59 (s, 3H), 0.87 (s, 9H), 0.02 (d, 6H, J = 4.2 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.8, 135.2, 133.1, 130.4, 129.8, 128.6, 118.5, 74.9, 72.8, 61.7, 46.5, 29.3, 26.0, 26.0, 25.9, 18.4, 18.1; $[\alpha]^{17}_D$ +22.3 (*c* 0.7, $CHCl_3$); HR-FABMS (*m*/*z*) calcd for $C_{23}H_{34}N_2O_5NaSi$ [M + Na]$^+$ 469.2129, found 469.2130; IR (KBr) ν 2956, 2929, 2858, 2114, 1718, 1380, 1271, 1109, 839, 779, 712 cm^{-1}.

(1*S*,4*S*,5*R*,7*R*)-4-((*tert*-Butyldimethylsilyloxy)methyl)-8,8-dimethyl-2-oxo-3-oxabicyclo[5.1.0]octan-5-yl Benzoate (11). To a refluxing solution of bis(*tert*-butylsalicylaldiminato)copper(II)[10] (7 mg, 0.0168 mmol) in anhydrous, deoxygenated toluene (10 mL) was added a solution of **10** (150 mg, 0.336 mmol) in deoxygenated toluene (10 mL) over 30 min under an argon atmosphere. The resulting mixture was refluxed for a further 30 min and then allowed to cool to room temperature. It was concentrated under reduced pressure and then purified by flash chromatography (PE:EtOAc = 50:1 to 30:1) to give 60 mg of **11** as a yellow oil in 42% yield. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.05 (d, 2H, J = 7.8 Hz), 7.61 (t, 1H, J = 7.2 Hz), 7.47 (t, 2H, J = 7.5 Hz), 5.35 (d, 1H, J = 7.2 Hz), 4.87−4.82 (m, 1H), 3.85 (d, 2H, J = 4.2), 2.38 (dd, 1H, J = 15.6, 3.3 Hz), 1.79 (d, 1H, J = 8.4 Hz), 1.51−1.41 (m, 1H), 1.26−1.22 (m, 1H), 1.19 (s, 3H), 1.14 (s, 3H), 0.86 (s, 9H), −0.04 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.2, 165.3, 133.4, 129.7, 129.6, 128.5, 78.1, 70.0, 62.9, 29.2, 27.6, 26.8, 25.8, 21.3, 19.9, 18.3, 16.7, −5.3, −5.4; $[\alpha]^{20}_D$ −40.4 (*c* 1.4, $CHCl_3$); HR-FABMS (*m*/*z*) calcd for $C_{23}H_{34}O_5NaSi$ [M + Na]$^+$ 441.2068, found 441.2083; IR (KBr) ν 3431, 2956, 2928, 2856, 1724, 1452, 1271, 839, 714 cm^{-1}.

(1*R*,4*R*,5*R*,7*S*)-4-((*tert*-Butyldimethylsilyloxy)methyl)-8,8-dimethyl-2-oxo-3-oxabicyclo[5.1.0]octan-5-yl Benzoate (5) and (1*S*,4*R*,5*R*,7*R*)-4-((*tert*-butyldimethylsilyloxy)methyl)-8,8-dimethyl-2-oxo-3-oxabicyclo[5.1.0]octan-5-yl Benzoate (14). According to the procedure for the synthesis of **11**, compound **13** was transformed to the intermediate diazoacetate in 75% yield. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.02 (d, 2H, J = 8.1 Hz), 7.54 (t, 1H, J = 7.2 Hz), 7.42 (t, 2H, J = 7.2 Hz), 5.41−5.35 (m, 1H), 5.24−5.13 (m, 2H), 4.75 (s, 1H), 3.75 (d, 1H, J = 5.4 Hz), 3.80 (dd, 1H, J = 12.6, 6.6 Hz), 1.65 (s, 3H), 1.59 (s, 3H), 0.86 (s, 9H), 0.01 (d, 6H, J = 1.2 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.8, 135.5, 133.0, 130.3, 129.7, 128.5, 118.0, 74.3, 72.2, 61.7, 46.3, 29.5, 25.9, 25.8, 18.2, 17.9, −5.4, −5.5; $[\alpha]^{20}_D$ +19.8 (*c* 0.45, $CHCl_3$); HR-FABMS (*m*/*z*) calcd for $C_{23}H_{34}N_2O_5NaSi$ [M + Na]$^+$ 469.2129, found 469.2130.

According to the procedure for the conversion of **10** into **11**, **5** and **14** were obtained (2.6:1, 58%). **5**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.00 (d, 2H, J = 7.8 Hz), 7.53 (t, 1H, J = 7.2 Hz), 7.40 (t, 2H, J = 7.6 Hz), 5.48−5.46 (m, 1H), 5.01−4.98 (m, 1H), 3.84 (d, 1H, J = 6.6 Hz), 1.66 (d, 1H, J = 8.4 Hz), 1.21−1.10 (m, 7H), 1.06−0.97 (m, 1H), 0.77 (s, 9H), −0.05 (s, 3H), −0.13 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.0, 165.4, 133.3, 129.8, 129.7, 128.5, 78.3, 70.3, 60.9, 29.3, 27.7, 27.0, 25.7, 22.8, 21.2, 18.1, 16.7, −5.5, −5.6; HR-FABMS (*m*/*z*) calcd for $C_{24}H_{34}O_5NaSi$ [M + Na]$^+$ 441.2073, found 441.2075; IR (KBr) ν 3475, 2927, 2856, 1716, 1454, 1269, 1027, 835, 711 cm^{-1}. **14**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.03 (d, 2H, J = 7.8 Hz), 7.55 (t, 1H, J = 7.2 Hz), 7.41 (t, 2H, J = 7.6 Hz), 5.18−5.13 (m, 1H), 4.67−4.61 (m, 1H), 3.94 (dd, 1H, J = 10.2, 6.3 Hz), 3.85 (dd, 1H, J = 10.2, 5.4 Hz), 2.08−2.00 (m, 1H), 1.76−1.66 (m, 1H), 1.58−1.49 (m, 1H), 1.28−1.92 (m, 1H), 1.16 (s, 3H), 1.06 (s, 3H), 0.84 (s, 9H), 0.02 (d, 6H, J = 5.4 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 166.0, 133.4, 129.9, 129.7, 128.6, 78.1, 74.0, 60.7, 27.4, 25.9, 25.6, 24.1, 24.0, 21.0, 18.3, 16.3, −5.3; $[\alpha]^{17}_D$ −28.9 (*c* 1.25, $CHCl_3$); HR-FABMS (*m*/*z*) calcd for $C_{23}H_{34}O_5NaSi$ [M + Na]$^+$ 441.2068, found 441.2085; IR (KBr) ν 2954, 2929, 2856, 1730, 1471, 1269, 1111, 1059, 837, 779, 714 cm^{-1}.

(*R*)-1-((1*S*,3*R*)-3-((*E*)-3-*tert*-Butoxy-2-methyl-3-oxoprop-1-enyl)-2,2-dimethylcyclopropyl)-3-((*S*)-hydroxy((*S*)-8-methyl-1,4-dioxaspiro[4.4]non-6-en-6-yl)methyl)but-3-en-2-yl Benzoate (25). To a solution of acetal bromide **24** (60 mg, 0.27 mmol) in THF (2 mL) was added *n*-butyllithium (1.6 M in hexane, 156 μL, 0.25 mmol) at −78 °C under an argon atmosphere and the mixture was stirred for 30 min at the same temperature. HMPA (7 μL, 0.04 mmol) was added and subsequently aldehyde **3** (18 mg, 0.04 mmol). After 1 h of stirring at −78 °C, the reaction was quenched by a saturated ammonium chloride solution. The aqueous layer was extracted with EtOAc. The combined organic phases were washed with brine and dried (Na_2SO_4). The crude was purified by flash chromatography on silica gel (PE:EtOAc = 6:1) to afford the desired compounds **25** (8 mg) and **26** (10 mg) (75% yield). **25**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.07 (d, 2H, J = 7.8 Hz), 7.57 (t, 1H, J = 7.5 Hz), 7.45 (t, 2H, J = 7.8 Hz), 6.45 (d, 1H, J = 10.2 Hz), 6.00 (s, 1H), 5.95 (s, 1H), 5.52 (dd, 1H, J = 3.9, 10.2 Hz), 5.44 (s, 1H), 5.40 (s, 1H), 4.80 (s, 1H), 4.01−3.87 (m, 4H), 3.20 (d, 1H, J = 3.0 Hz), 2.72 (m, 1H), 2.28 (dd, 1H, J = 7.5, 13.5 Hz), 1.95−1.83 (m, 5H), 1.62−1.55 (m, 1H), 1.48−1.35 (m, 10H), 1.18−1.04 (m, 9H); HR-FABMS (*m*/*z*) calcd for $C_{33}H_{44}O_7Na$ [M + Na]$^+$ 575.2985, found 575.2996. **26**: ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.04 (d, 2H,

J = 7.2 Hz), 7.54 (t, 1H, J = 7.5 Hz), 7.42 (t, 2H, J = 7.5 Hz), 6.47 (d, 1H), 5.85 (s, 1H), 5.66 (t, 1H), 5.47 (s, 1H), 5.40 (s, 1H), 4.96 (s, 1H), 4.01−3.86 (m, 4H), 2.72−2.58 (m, 1H), 2.24−2.18 (m, 1H), 1.96 (t, 1H, J = 6.9 Hz), 1.84 (s, 3H), 1.47−1.36 (m, 10H), 1.07 (s, 3H), 1.05 (s, 3H), 0.73 (d, 3H, J = 6.6 Hz); HR-FABMS (m/z) calcd for $C_{33}H_{44}O_7Na$ $[M + Na]^+$ 575.2979, found 575.2996.

(*R*)-3-((*S*)-Acetoxy-((*S*)-8-methyl-1,4-dioxaspiro[4.4]non-6-en-6-yl)methyl)-1-((1*S*,3*R*)-3-((*E*)-3-*tert*-butoxy-2-methyl-3-oxoprop-1-enyl)-2,2-dimethylcyclopropyl)but-3-en-2-yl Benzoate (27). Ac_2O (80 μL, 0.85 mmol), pyridine (200 μL, 2.5 mmol), and DMAP (1 mg, 0.008 mmol) were added to a solution of **25** (10 mg, 0.019 mmol) in 1 mL of CH_2Cl_2 at 0 °C. After 4 h of stirring at room temperature, the crude was purified by flash chromatography on silica gel (PE:EtOAc = 10:1) to afford 7 mg of the desired compound **27** (69%). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.06 (d, 2H, J = 8.1 Hz), 7.56 (t, 1H, J = 7.2 Hz), 7.44 (t, 2H, J = 7.8 Hz), 6.45 (d, 1H, J = 9.9 Hz), 6.04 (s, 1H), 5.95 (s, 1H), 5.60 (t, 1H, J = 6.0 Hz), 5.40 (s, 1H), 5.36 (s, 1H), 3.94−3.78 (m, 4H), 2.65−2.79 (m, 1H), 2.28 (dd, 1H, J = 7.2, 13.5 Hz), 1.97−1.83 (m, 8H), 1.68−1.60 (m, 1H), 1.48−1.38 (m, 10H), 1.10−0.96 (m, 10H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.9, 167.5, 165.6, 145.4, 143.6, 138.8, 133.1, 130.1, 129.9, 128.6, 119.0, 114.6, 79.9, 74.3, 68.1, 65.4, 64.9, 45.1, 35.4, 30.1, 29.1, 29.0, 28.3, 27.3, 24.0, 21.3, 20.6, 16.1, 13.0; HR-FABMS (m/z) calcd for $C_{35}H_{46}O_8Na$ $[M + Na]^+$ 617.3085, found 617.3077.

(*E*)-3-((1*R*,3*S*)-3-((*R*)-3-((*S*)-Acetoxy-((*S*)-3-methyl-5-oxocyclopent-1-enyl)methyl)-2-(benzoyloxy)but-3-enyl)-2,2-dimethylcyclopropyl)-2-methylacrylic Acid (Lathyranoic Acid A, 1). To a solution of **27** (5 mg, 0.08 mmol) in a mixture of acetone (1 mL) and water (40 μL) was added p-TsOH (cat.). After 10 min of stirring at room temperature the reaction solution was concentrated and dissolved in CH_2Cl_2 (2 mL), dried (Na_2SO_4), filtered, and concentrated. The residue was purified by flash chromatography on silica gel (PE:EtOAc = 8:1) to give intermediate ketone (4 mg). ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.04 (d, 2H, J = 7.2 Hz), 7.56 (t, 1H, J = 7.2 Hz), 7.47−7.42 (m, 3H), 6.46 (d, 1H, J = 6.9 Hz), 6.06 (s, 1H), 5.46 (t, 1H, J = 6.6 Hz), 5.41 (s, 1H), 5.34 (s, 1H), 2.95 (m, 1H), 2.66 (dd, 1H, J = 6.3, 18.6 Hz), 2.02 (dd, 1H, J = 2.1, 18.9 Hz), 1.97−1.92 (m, 1H), 1.89 (s, 3H), 1.85 (s, 3H), 1.47−1.37 (m, 10H), 1.17 (d, 3H, J = 7.2 Hz), 1.14−1.09 (m, 1H), 1.07 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 206.3, 169.6, 167.5, 165.7, 167.7, 144.3, 142.4, 138.5, 133.3, 130.5, 129.9, 128.6, 115.9, 80.0, 74.2, 68.1, 43.9, 33.9, 30.3, 29.9, 29.0, 29.0, 28.4, 27.4, 24.0, 21.0, 20.0, 16.1, 13.0. To a solution of the ketone product above (4 mg, 0.007 mmol) in anhydrous CH_2Cl_2 was added TFA (0.2 mL, 3.2 mmol) dropwise at 0 °C. After 30 min of stirring at room temperature the reaction mixture was concentrated and the residue was purified by flash chromatography on silica gel (PE:EtOAc:acetone = 7:1:3) to give the desired product (3 mg) in 72% yield in two steps. ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.05 (d, 2H, J = 7.8 Hz), 7.57 (t, 1H, J = 6.9 Hz), 7.47−7.43 (m, 3H), 6.67 (d, 1H, J = 10.2 Hz), 6.03 (s, 1H), 5.42−5.38 (m, 2H), 5.33 (s, 1H), 3.03−2.92 (m, 1H), 2.68 (dd, 1H, J = 6.0, 18.6 Hz), 2.06−1.99 (m, 2H), 1.93−1.89 (m, 5H), 1.49−1.42 (m, 1H), 1.21−1.14 (m, 4H), 1.11 (s, 3H), 1.09 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 206.5, 171.4, 169.4, 166.0, 165.4, 144.2, 142.4, 142.0, 133.1, 130.1, 129.6, 128.4, 127.5, 115.1, 73.8, 67.6, 43.6, 33.7, 30.2, 29.7, 28.8, 27.6, 24.9, 20.8, 19.8, 16.0, 12.3; $[\alpha]^{25}_D$ −25 (c 0.15, $CHCl_3$); HR-ESIMS (m/z) calcd for $C_{29}H_{34}O_7Na$ $[M + Na]^+$ 517.2197, found 517.2197; IR (KBr) ν 3492, 2958, 2929, 1701, 1633, 1452, 1367, 1270, 1117, 1026, 714 cm^{-1}.

These spectroscopic data matched those reported for natural product **1** (see the Supporting Information).

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Supporting Information Available: Experimental details, characterization data including the crystallographic data, and copies of the ^{1}H and ^{13}C NMR spectra of the synthetic intermediates. This material is available free of charge via the Internet at http://pubs.acs.org.