SUPPORTING INFORMATION

Oversized ubiquinones as molecular probes for structural dynamics of the ubiquinone reaction site in mitochondrial respiratory complex I

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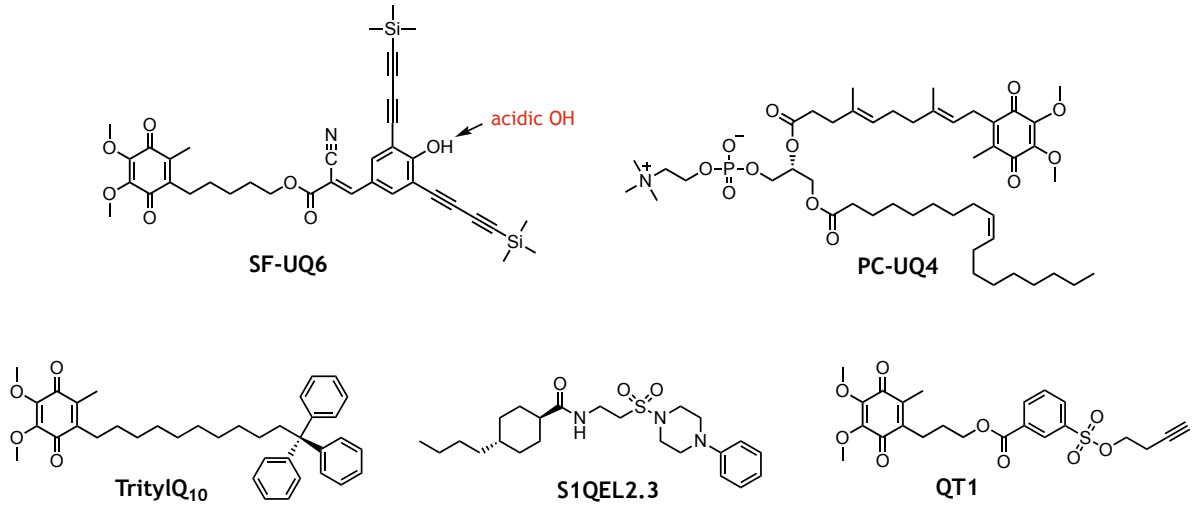


Figure S1

Structures of the artificial ubiquinones or inhibitor mentioned in the text.

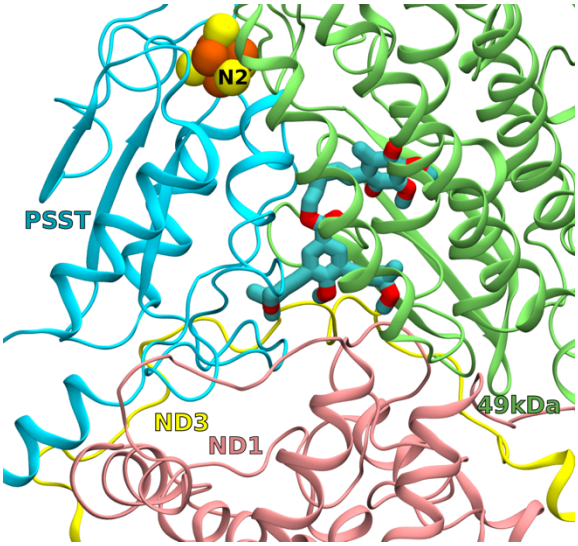


Figure S2

Simulation snapshot of OS-UQ3 molecule at the reaction site nearby the Fe-S cluster N2.

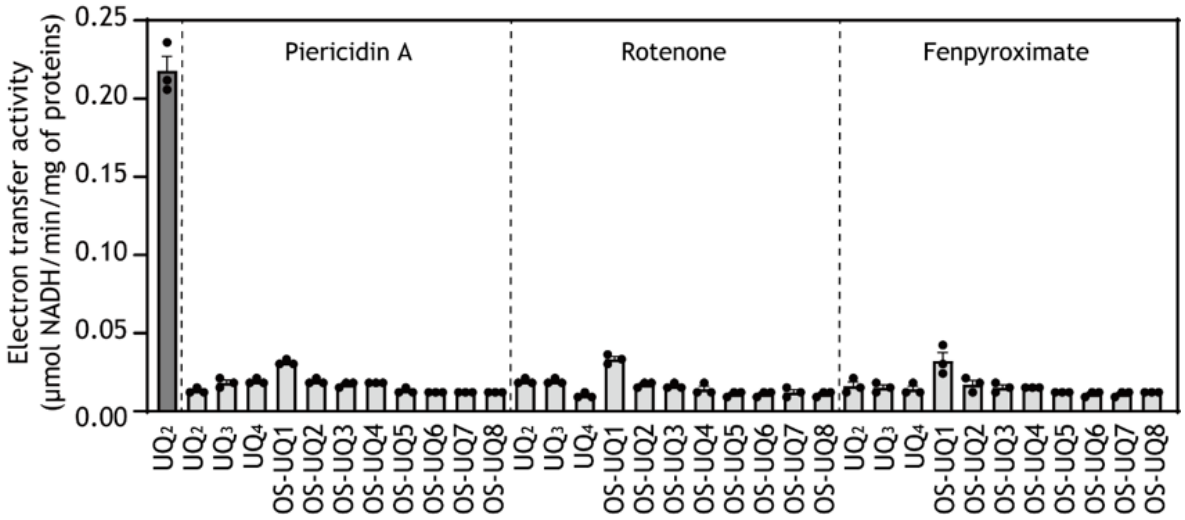


Figure S3

The electron transfer (NADH-UQ oxidoreductase) activities of OS-UQ1–OS-UQ8 in SMPs in the presence of piericidin A (panel A), rotenone (panel B), or fenpyroximate (panel C) (5.0 μM each). As a reference, the activities of UQ_2 in the presence (*gray*) and absence (*black*) of inhibitor are shown. The experimental conditions are identical to those used in Figure 3.

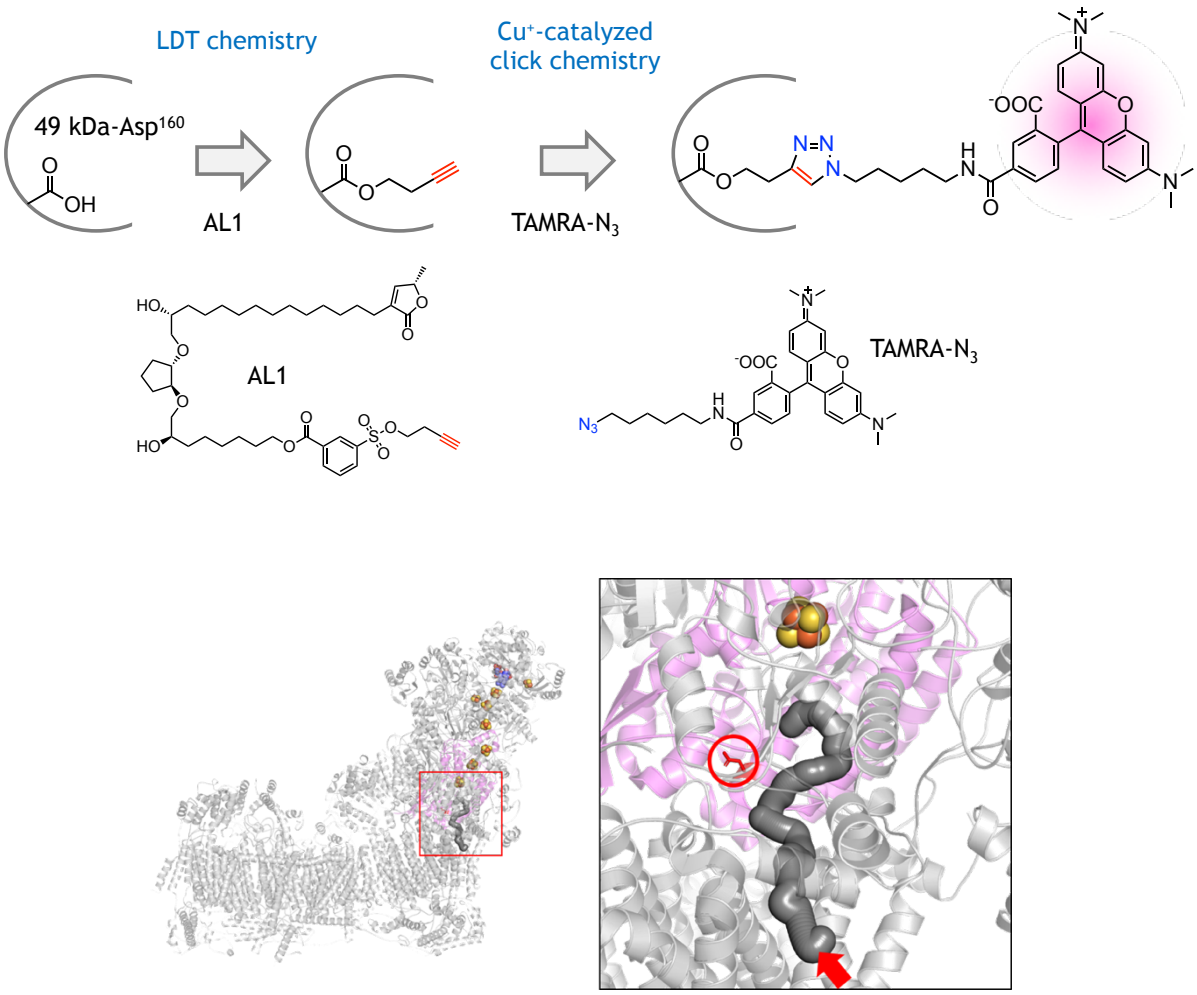


Figure S4

An upper panel: schematic diagram of the pinpoint chemical modification of the 49 kDa-Asp^{160}. The 49 kDa-Asp^{160} can be alkynylated by AL1 (a first step) and visualized by conjugating a fluorescent tag TAMRA-N_3 to Asp^{160}(COO)-$(CH_2)_2$-C≡CH via a Cu^+-catalyzed click chemistry after solubilizing SMPs (a second step). For details, see refs. 19 and 22.

A lower panel: the position of 49 kDa-Asp^{160} (marked by a *red circle*) in the predicted UQ-access channel in bovine complex I (ref. 7). The 49-kDa subunit is colored in *pink*. The channel was generated using MOLE with a 1.4 Å probe (https://mole.upol.cz) (Pravda *et al*. (2018) *Nucleic Acids Res.* 46, W368-W373) and is shown in *black*. A red arrow indicates an entry point to the channel.

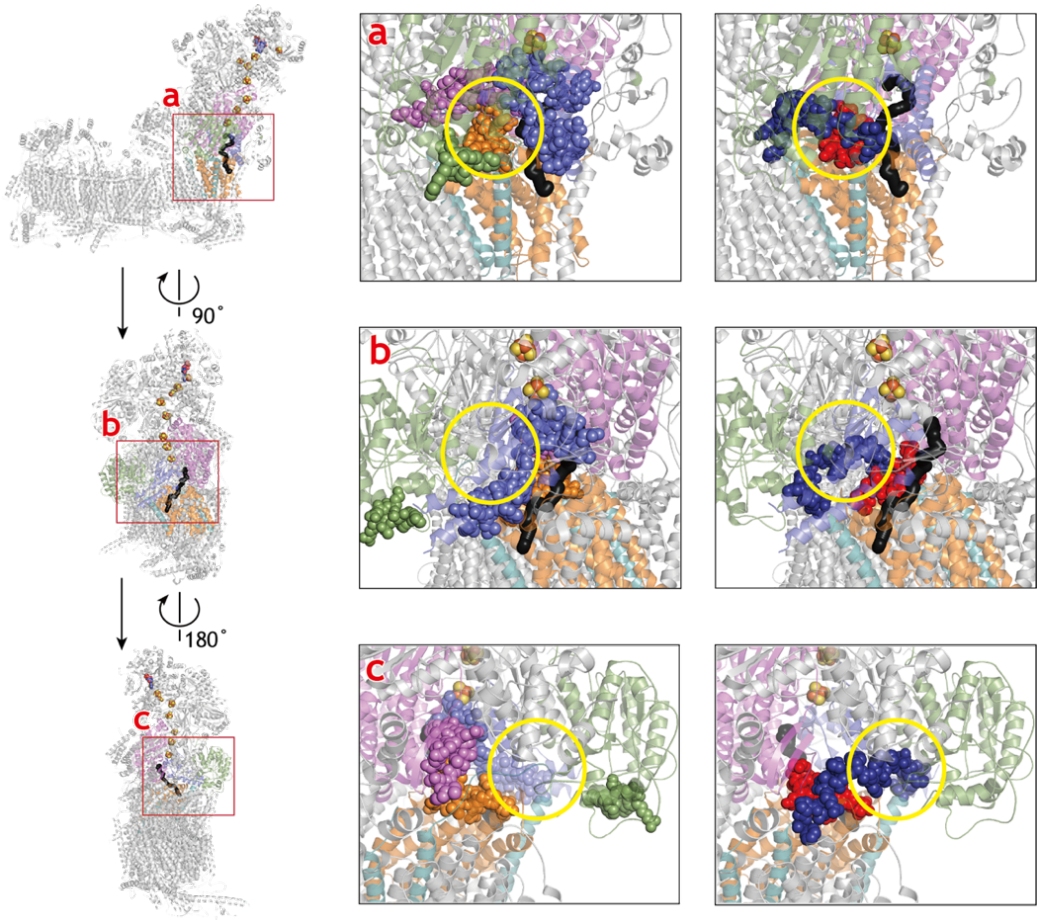


Figure S5

The putative open access path for oversized UQs in complex I. The entrance of the putative open access path is marked by *yellow circle* (middle and right panels). The two flexible loops (TMH1-2 in ND3 (*dark blue sphere*) and TMH5-6 in ND1 (*red sphere*)) are highlighted in the right panel. The left panel shows the position of the close-up (middle and right panels) in the whole enzyme. The quinone-access channel predicted in the current models was generated using MOLE with a 1.4 Å probe (https://mole.upol.cz) (Pravda *et al*. (2018) *Nucleic Acids Res*. 46, W368-W373) and is shown in *black*.

The entrance of the putative path (*yellow circle*) is located in the area where the regions photoaffinity-labeled by different types of inhibitors are in contact or close to one other: the labeled regions are Val44–Glu67 of the 49-kDa subunit (labeled by quinazoline (*40*, *41*), [^{125}I]PRA4, [^{125}I]PRA5, and [^{125}I]PRA6 (*17*), in *pink sphere*), Lys33–Tyr67 of the PSST subunit (labeled by fenpyroximate (*39*) and [^{125}I]PRA5 (*17*), in *blue sphere*), the loop connecting TMH5–6 of ND1 subunit (labeled by quinazoline (*40*), bullatacin (*42*), and [^{125}I]PRA6 (*17*), in *yellow sphere*), and the *C*-terminal domain Thr227–Pro252 of 39-kDa subunit (labeled by [^{125}I]PRA3 (*17*), in *green sphere*). Note that while we previously identified the peptide Thr227–Lys283 of the 39-kDa subunit as the labeled region by [^{125}I]PRA3, here we presented a solely hydrophobic segment, Thr227–Pro252, since this segment could be anchored to the membrane part via hydrophobic α-helices and, hence, the putative binding site of [^{125}I]PRA3 (*17*). In this figure, ovine complex I (PDB entry 5LNK, ref. 9) was used because the matrix-side third loop (Thr201−Ala217) connecting the TMH5−6 of ND1 is disordered in the deactive state of the bovine enzyme (*7*, *8*).

Figure S6

Analysis of the extracted phospholipids by thin layer chromatography (TLC) using a chloroform/methanol/water (65:25:4) mixture as an eluent. TLC was performed on Merk TLC plate silica-gel $60F^{254}$ and the spots were detected by phosphomolybdic acid. BE, phospholipids extracted from isolated bovine heart mitochondria in our laboratory; PE, phosphatidylethanolamine (Avanti Polar Lipid, Inc.); CL, cardiolipin (Avanti Polar Lipid, Inc.); PC, phosphatidylcholine (1,2-dioleoyl-*sn*-glycero-3-phosphocholine, NOF Corp., Japan). PE and CL purchased from Avanti Polar Lipid were the extracts from bovine heart mitochondria, which are a mixture of different acyl chain compositions.

General procedures for the syntheses

All moisture- and air-sensitive reactions were performed in oven-dried glassware under Ar (or N_2) atmosphere with dry solvents using standard syringe septum techniques. ^{1}H- and ^{13}C-NMR spectra were recorded at 400 and 100 MHz, respectively, with Bruker AVANCE III 400 spectrometer using tetramethylsilane (TMS) as an internal standard. Chemical shifts (δ) are given in ppm relative to TMS with a coupling constant (J) in Hz. The mass spectra were recorded on a Shimadzu LCMS-8040 with ESI source at positive or negative mode. Thin-layer chromatography (TLC) was performed on Merk TLC plate silica-gel 60F^{254}, and the spot was detected by iodine, anis, phosphomolybdic acid or UV absorbance. Dry solvents were used either as purchased or freshly distilled using common practices where appropriate.

Abbreviations

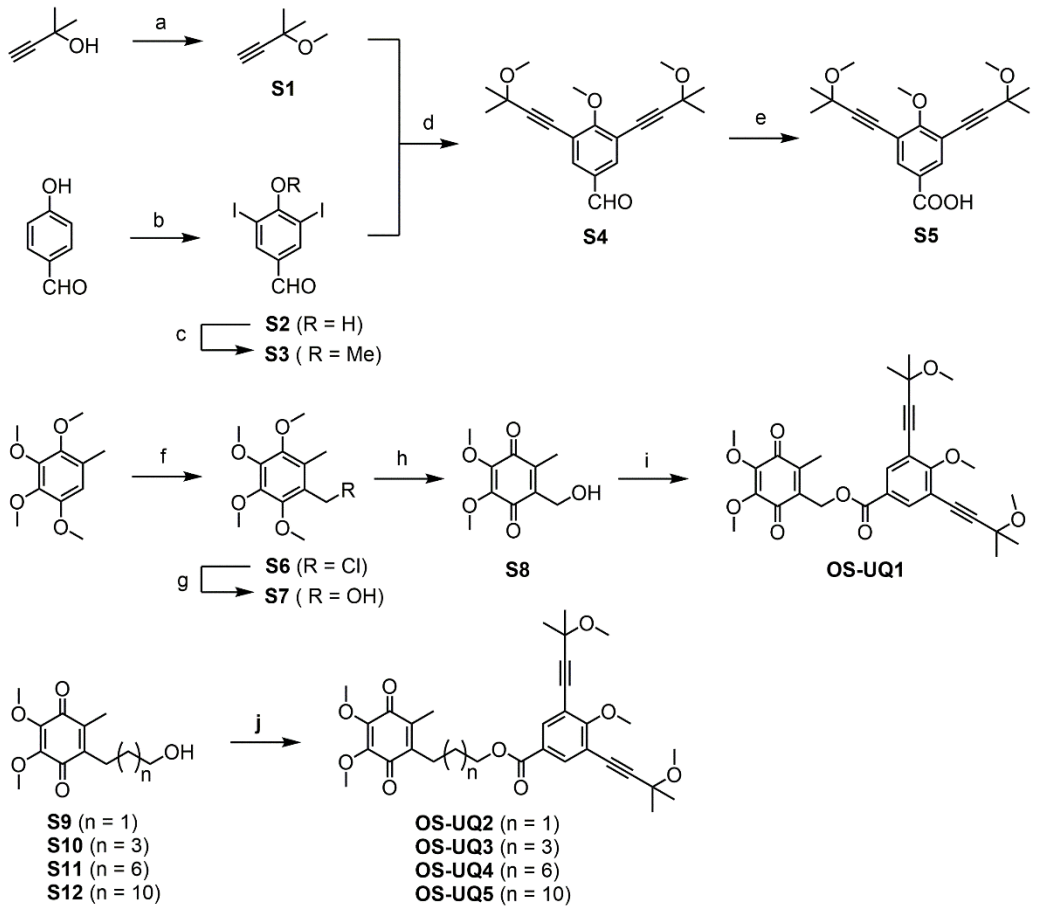
AcOH, acetic acid; Bu_4NBr, tetrabutyl ammonium bromide; *t*-BuOH, *tert*-butylalcohol; *t*-BuOK, potassium *tert*-butoxide; CAN, cerium ammonium nitrate; $(CHOH)_n$, paraformaldehyde; DIBAL-H, diisobutylaluminium hydride; DMAP, 4-dimethylaminopyridine; DMF, dimethylformamide; EDC, 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide hydrochloride; Et_3N, triethylamine; Et_2O, diethylether; EtOAc, ethyl acetate; $LiBHEt_3$, lithium triethylborohydride; Me_2SO_4, dimethyl sulfate; NBS, *N*-bromosuccinimide; NMBA, 2-methyl-6-nitrobenzoic anhydride; rt, room temperature; TBAF, tetrabutylammonium fluoride; TBS, *tert*-butyldimethylsilyl; TBHP, *tert*-butyl hydroperoxide; THF, tetrahydrofuran.

Outline of the syntheses of OS-UQ1−US-UQ5

The synthetic procedures of **OS-UQ1**−**OS-UQ5** are outlined in Scheme S1. Methylation of 2-methyl-3-butyn-1-ol by Me_2SO_4 gave **S1**. In parallel, the commercially available 4-hydroxybenzaldehyde was treated with KI in the presence of $NaIO_4$ and NaCl to provide **S2** [*1*], whose phenolic hydroxy group was methylated by Me_2SO_4 to give **S3**. Sonogashira-type cross-coupling [*2*] of **S1** with diiodide **S3** gave aldehyde **S4**, which was further oxidized by the method of Bal et al. [*3*].

Treatment of 2,3,4,5-tetramethoxytoluene with paraformaldehyde in the presence of HCl gave **S6** [*4*], followed by the treatment with aq. NaOH in the presence of Bu_4NBr. CAN oxidation of **S7** provided **S8**, which was subjected to esterification with **S5** using NMBA/DMAP to provide **OS-UQ1**. **OS-UQ2**−**OS-UQ5** were prepared by esterification of appropriate UQ analogues (**S9**−**S12**, *ref. 5*) using EDC/DMAP.

Scheme S1[a]



[a]*Reagents and conditions*: (a) NaH, Me_2SO_4, DMF, rt, 5.5 h, 61%; (b) $NaIO_4$, NaCl, KI, AcOH/H_2O (9:1), 50 ˚C, 24 h, 65%; (c) NaH, Me_2SO_4, DMF, rt, 22 h, 52%; (d) $PdCl_2(PPh_3)_2$, CuI, Et_3N, 40 ˚C, 24 h, 65%; (e) $NaH_2PO_4 \cdot 2H_2O$, 2-methyl-2-butene, $NaClO_2$, *t*-BuOH/H_2O (5:1), rt, 3 h, 93%; (f) $(CHOH)_n$, conc. HCl, 40 ˚C, 5 h, 96%; (g) Bu_4NBr, aq. NaOH, 100 ˚C, 30 min, 92%; (h) CAN, THF/H_2O (1:1), 0 ˚C, 2.5 h, 63%; (i) **S5**, NMBA, DMAP, CH_2Cl_2, rt, 16 h, 61%; (j) **S5**, EDC, DMAP, CH_2Cl_2, rt, 14 h, 61%.

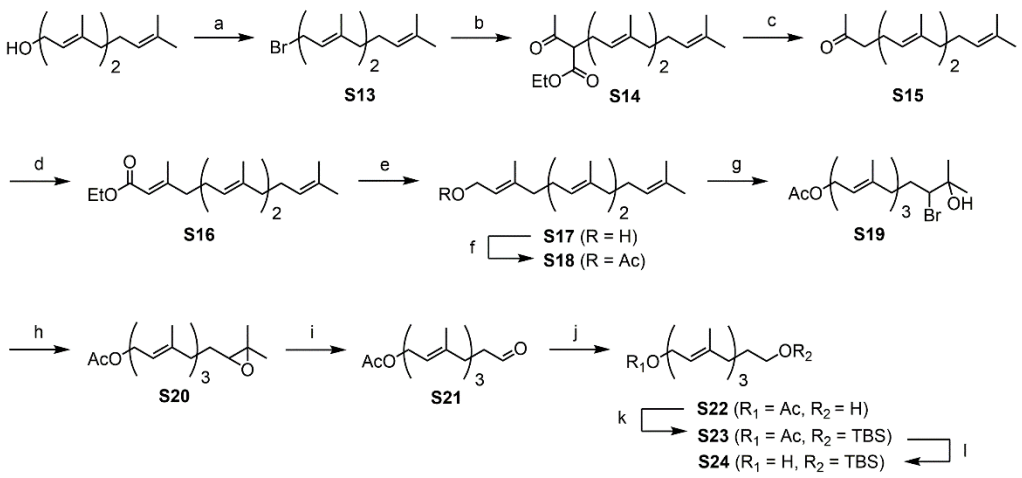
Outline of the synthesis of OS-UQ6−US-UQ8

The synthetic procedures of **OS-UQ6−US-UQ8** are outlined in Schemes S2, S3, S4 and S5. One key intermediate **S24**, containing three prenyl units, were synthesized from commercially available *trans-trans*-farnesyl acetate as a starting material (Scheme S2). Allyl bromide **S13** was treated with ethyl acetoacetate in the presence of NaOMe to give **S14**. Decarboxylation of **S14** in the presence of KOH provided ketone **S15**. Horner-Wadworth-Emmons reaction [*6*] of the ketone **S15** provide the ester **S16**, which was treated with DIBAL-H, followed by the acetylation of the hydroxy group. Treatment of acetate **S18** with NBS gave the bromohydrin **S19**, which was immediately converted to the epoxide **S20** in the presence of NaH. Oxidative cleavage of **S20** by $NaIO_4/H_5IO_6$ and subsequent reduction of **S21** by $NaBH_4$ gave alcohol **S22**, whose hydroxy group was protected by TBS-group to afford **S23**. Treatment of **S23** with K_2CO_3 furnished **S24**.

A key intermediate **S31**, containing five prenyl units, was synthesized according to the methods by Roe *et al.* [*7*] (Scheme S3). Prenyl sulfone **S27** and bromide **S29** were prepared according to the procedures as described elsewhere [*7, 8*]. The carbanion of sulfone **S27,** which was prepared by the treatment with NaH, was alkylated with bromide **S29**, providing (all-*E*)-benzene sulfonyl five prenyl alcohol **S30**. The benzenesulfonyl group was removed via Pd-catalyzed reaction in the presence of super-hydride $LiBHEt_3$ to give **S31**. Another intermediate **S37**, containing eight prenyl units, was prepared according to the procedures described in *ref. 8*, using commercially available solanesol as a starting material (Scheme S4).

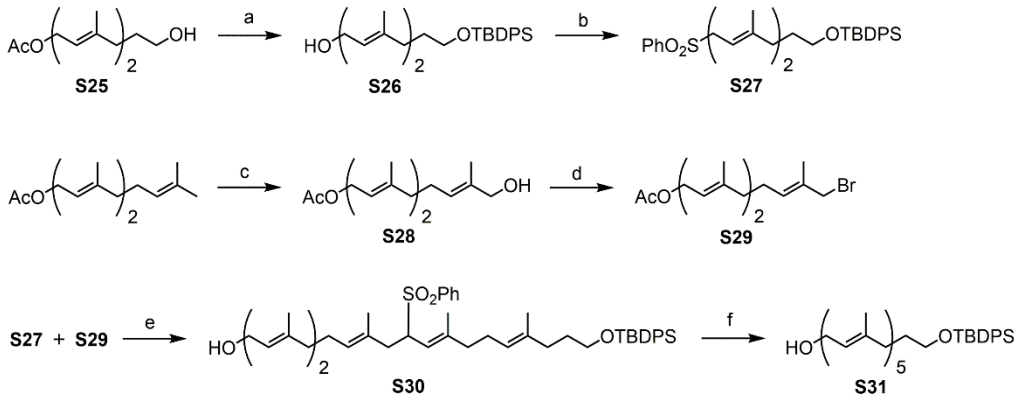
OS-UQ6−OS-UQ8 were synthesized from the prenyl intermediates **S24**, **S31**, and **S37**, respectively, as outlined in Scheme S5. Esterification of **S5** with appropriate intermediates **S45−S47**, which were prepared from **S24**, **S31**, and **S37**, respectively, gave **OS-UQ6−OS-UQ8**.

Scheme S2[b]



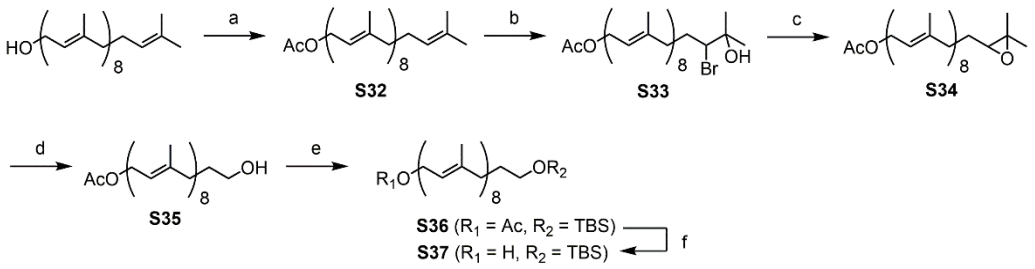
[b]*Reagents and conditions*: (a) PBr_3, Et_2O, 0 ˚C, 1 h, 92%; (b) MeONa, ethyl acetoacetate, MeOH/dioxane (5:3), rt, 17 h, 31%; (c) 5.0 M aq. KOH, MeOH, 80 ˚C, 2.5 h, 59%; (d) NaH, triethylphosphono acetate, 15-crown-5- ether, THF, rt, 40 h, 97%; (e) DIBAL-H, Et_2O, -78 ˚C, 50 min, 97%; (f) Ac_2O, DMAP, Et_3N, CH_2Cl_2, rt, 3 h, 94%; (g) NBS, THF/H_2O (2:1), 0 ˚C, 1.5 h, 58%; (h) NaH, THF, rt, 13 h, 87%; (i) $NaIO_4$, H_5IO_6, THF/H_2O (2:1), rt, 4 h, 77%; (j) $NaBH_4$, MeOH, -10 ˚C, 3 h, 81%; (k) imidazole, DMAP, TBS-Cl, CH_2Cl_2, rt, 1.5 h, 98%; (l) K_2CO_3, MeOH, rt, 1.5 h, 80%.

Scheme S3[c]



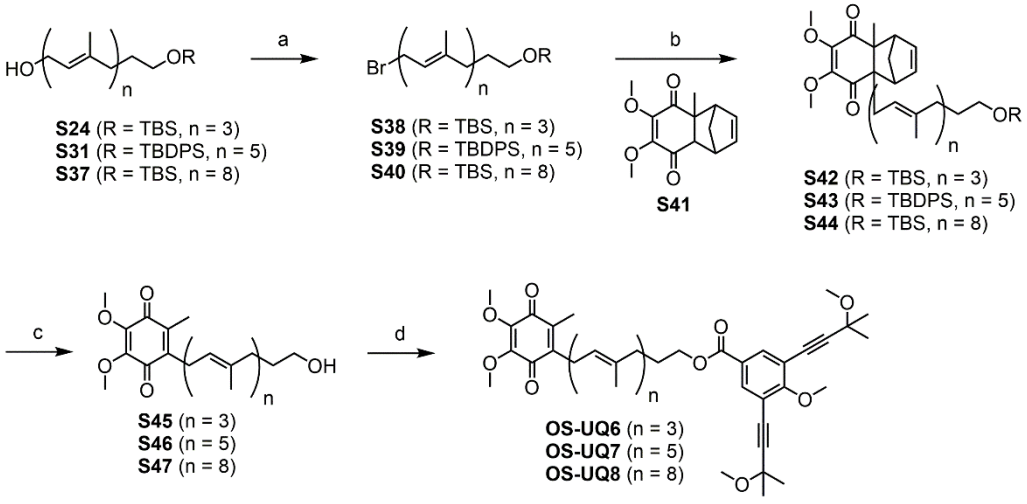
[c]*Reagents and conditions*: (a) i) TBDPS-Cl, imidazole, DMF, rt, 1 h, ii) K_2CO_3, MeOH, rt, 1.5 h, 91% (2 steps); (b) i) MsCl, LiBr, Et_3N, THF, 0 ˚C, 1 h, ii) $SO_2Ph \cdot 2H_2O$, DMF, rt, 14 h, 83% (2 steps); (c) i) SeO_2, salicylic acid, TBHP, CH_2Cl_2, 0 ˚C, 3 days, ii) $NaBH_4$, MeOH, 0 ˚C, 8 h, 21% (2 steps); (d) MsCl, LiBr, Et_3N, THF, 0 ˚C, 2 h, 92%; (e) i) NaH, DMF, 0 ˚C, 12 h, ii) K_2CO_3, MeOH, rt, 1 h, 52% (2 steps); (f) $LiBHEt_3$, $Pd(dppp)Cl_2$, THF, 1 h, 66%.

Scheme S4[d]



[d]*Reagents and conditions*: (a) Ac_2O, DMAP, Et_3N, CH_2Cl_2, rt, 3 h, 96%; (b) NBS, THF/H_2O (2:1), 0 ˚C, 4 h, 50%; (c) NaH, THF, rt, 18 h, 72%; (d) i) $NaIO_4$, H_5IO_6, THF/H_2O (4:1), rt, 19 h, ii) $NaBH_4$, MeOH, rt, 3 h, 46% (2 steps); (e) DMAP, TBS-Cl, Et_3N, CH_2Cl_2, rt, 6 h, 90%; (f) K_2CO_3, MeOH, rt, 3.5 h, 86%.

Scheme S5[e]



[e]*Reagents and conditions*: (a) MsCl, LiBr, Et_3N, THF, -20 ˚C, 2 h, 72-96% (b) **S41**, *t*-BuOK, DMF/THF (3:1), -40 ˚C, 2 h, 56-68%; (c) i) toluene, reflux, 2 h, ii) THF/1.0 M aq. HCl (3:1), rt, 1 h, 85-92% (2 steps) or TBAF, AcOH, THF, rt, 20 h, 59% (2 steps); (d) **S5**, EDC, DMAP, rt, 10-15 h, 49-69%.

Syntheses of OS-UQ1−US-UQ5

*Synthesis of **S1***

To a suspension of NaH (2.14 g, 60% in mineral oil, 53.5 mmol) in anhydrous DMF (30 mL), a solution of 2-methyl-3-butyn-1-ol (3.0 g, 35.6 mmol) in DMF (5 mL) was added at 0 ˚C under N_2 atmosphere. After the mixture was stirred for 30 min at 0 ˚C, dimethyl sulfate (5.39 g, 42.7 mmol) was added to the mixture, and the mixture was stirred for 5 h at rt. The reaction mixture was quenched with AcOH (2 mL), then the mixture was subjected to the distillation at 80 ˚C under normal pressure to provide **S1** as a colorless oil (2.12 g, 21.6 mmol, 61%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 3.37 (s, 3H), 2.42 (s, 1H), 1.46 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 85.88, 72.24, 70.52, 51.82, 28.42 (2C).

*Synthesis of **S2***

To a solution of 4-hydorxybenzaldehyde (4.0 g, 32.8 mmol) in a mixture of AcOH (45 mL) and H_2O (5 mL), $NaIO_4$ (7.0 g, 32.8 mmol), NaCl (3.3 g, 66 mmol), and KI (11.0 g, 66 mmol) were added at rt, and the mixture was stirred for 15 h at rt. The mixture was stirred for a further 5 h at 70 ˚C, then, the reaction was quenched with ice water to form precipitate. The precipitate was filtered off, washed with water and dried in a desiccator to provide **S2** as a white solid (12.2 g, 32.6 mmol, 99%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 9.74 (s, 1H), 8.20 (s, 2H), 6.27 (br s, 1H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 187.86, 158.55, 141.24 (2C), 133.08, 82.88 (2C); ESI-MS (*m/z*): 372.8 $[M-H]^-$.

*Synthesis of **S3***

To a suspension of NaH (118 mg, 60% in mineral oil, 2.94 mmol) in anhydrous DMF (7 mL), **S2** (1.0 g, 2.67 mmol) was added at 0 ˚C under N_2 atmosphere. After stirring for 30 min at rt, dimethyl sulfate (370 mg, 2.94 mmol) was added, and the mixture was stirred for 22 h at rt. The reaction mixture was cooled to 0 ˚C, quenched with saturated aqueous NH_4Cl, extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 10% EtOAc/*n*-hexane) to provide **S3** as a white solid (538 mg, 1.39 mmol, 52%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 9.81 (s, 1H), 8.27 (s, 2H), 3.93 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 188.26, 163.95, 141.43 (2C), 135.63, 91.44 (2C), 61.10.

*Synthesis of **S4***

To a solution of **S3** (538 mg, 1.39 mmol) and **S1** (339 mg, 3.46 mmol) in Et_3N (15 mL), $PdCl_2(PPh_3)_2$ (49 mg, 0.07 mmol) and CuI (13 mg, 0,07 mmol) were added at rt under Ar atmosphere, and the reaction mixture was allowed to warm to 40 ˚C and stirred for 28 h. The mixture was cooled to 0 ˚C, quenched with saturated aqueous NH_4Cl, extracted with Et_2O, and dried over anhydrous $MgSO_4$. The crude product

was purified by silica gel column chromatography (Wako gel® C-200, 5-10% EtOAc/*n*-hexane) to provide **S4** as a yellow oil (298 mg, 0.91 mmol, 65%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 9.87 (s, 1H),7.87 (s, 2H), 4.14 (s, 3H), 3.45 (s, 6H), 1.57 (s, 12H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 189.88, 166.29, 135.08 (2C), 131.71, 117.65 (2C), 97.40 (2C), 79.18 (2C), 71.21 (2C), 61.28, 52.04 (2C), 28.33 (4C).

*Synthesis of **S5***

To a solution of **S4** (298 mg, 0.91 mmol), $NaH_2PO_4 \cdot 2H_2O$ (142 mg, 0.91 mmol), and 2-methyl-2-butene (435 µL, 4.1 mmol) in *t*-BuOH/H_2O (5 mL:1mL), $NaClO_2$ (244 mg, 2.7 mmol) was added, and the mixture was stirred for 3 h at rt. The reaction mixture was diluted with 1.0 M aqueous HCl, extracted with $CHCl_3$ and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 60% EtOAc/*n*-hexane) to provide **S5** as a white solid (292 mg, 0.85 mmol, 93%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.09 (s, 2H), 4.12 (s, 3H), 3.47 (s, 6H), 1.58 (s, 12H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 170.21, 165.89, 135.76 (2C), 124.66, 117.17 (2C), 96.88 (2C), 79.39 (2C), 71.33 (2C), 61.24, 52.03 (2C), 28.35 (4C).

*Synthesis of **S6***

2,3,4,5-Tetramethoxytoluene (1.5 g, 7.1 mmol) and paraformaldehyde (320 mg, 10.6 mmol) was dissolved in conc. HCl (10 mL), and the mixture was stirred at 40 ˚C for 5 h. The reaction mixture was diluted with water, extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20% EtOAc/*n*-hexane) to provide **S6** as a colorless oil (1.77 g, 6.8 mmol, 96%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 4.69 (s, 2H), 3.93 (s, 3H), 3.92 (s, 3H), 3.90 (s, 3H), 3.79 (s, 3H), 2.29 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 148.73, 148.27, 147.94, 144.96, 126.90, 125.00, 61.98, 61.31 (2C), 60.98, 38.86, 11.39.

*Synthesis of **S7***

To a solution of **S6** (700 mg, 2.69 mmol) in water (10 mL), Bu_4NBr (870 mg, 2.69 mmol) and NaOH (12 mg, 0.30 mmol) were added at rt, and the mixture was stirred at 100 ˚C for 2 h. The reaction mixture was cooled to rt, extracted with EtOAc, and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20-50% EtOAc/*n*-hexane) to provide **S7** as a colorless oil (602 mg, 2.48 mmol, 92%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 4.69 (s, 2H), 3.92 (s, 3H), 3.90 (s, 3H), 3.89 (s, 3H), 3.79 (s, 3H), 2.27 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 148.70, 148.29, 147.17, 144.81, 127.70, 126.20, 61.89, 61.32, 61.30, 60.91, 57.72, 11.60; ESI-MS (*m/z*): 242.3 $[M+H]^+$.

*Synthesis of **S8***

To an ice-cooled solution of **S7** (602 mg, 2.48 mmol) in a mixture of THF (10 mL) and H_2O (10 mL), CAN (2.53 g, 4.62 mmol) was added, and the mixture was stirred at 0 ˚C for 2.5 h. The reaction mixture was extracted with CH_2Cl_2 and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 40-70% EtOAc/*n*-hexane) to provide **S8** as an orange solid (380 mg, 1.57 mmol, 63%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 4.51 (s, 2H), 3.98 (s, 3H), 3.98 (s, 3H), 2.07 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 185.40, 184.70, 145.05, 144.42, 140.66, 138.90, 61.43, 61.41, 57.20, 11.80.

*Synthesis of **OS-UQ1***

To a solution of **S5** (24 mg, 0.070 mmol) and **S8** (15 mg, 0.070 mmol) in CH_2Cl_2 (5 mL), MNBA (30 mg, 0.085 mmol) and DMAP (11 mg, 0.085 mmol) were added under N_2 atmosphere, and the mixture was stirred for 16 h at rt. The reaction was quenched with saturated aqueous NH_4Cl, extracted with CH_2Cl_2, and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20% EtOAc/*n*-hexane) to provide **OS-UQ1** as an orange oil (23 mg, 0.043 mmol, 61%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.00 (s, 2H), 5.23 (s, 2H), 4.08 (s, 3H), 4.06 (s, 3H), 4.02 (s, 3H), 3.44 (s, 6H), 2.17 (s, 3H), 1.55 (s, 12H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.28, 182.91, 165.58, 164.73, 144.94, 144.05, 135.16 (2C), 124.79, 122.00, 117.19 (2C), 96.94 (2C), 79.29 (2C), 71.20 (2C), 61.48, 61.46, 61.20, 57.76, 52.02 (2C), 28.34 (4C), 12.52; ESI-MS (*m/z*): 539.2 $[M+H]^+$, 561.2 $[M+Na]^+$.

*Synthesis of **S9**, **S10**, **S11**, and **S12***

These compounds were synthesized in 5 steps according to the procedures described in *ref. 5* using commercially available 1,3-propanediol, 1,5-pentanediol, 1,8-octanediol, and 1,12-dodecanediol as a starting material, respectively. **S9**: ^{1}H-NMR (400 MHz, $CDCl_3$): δ 4.00 (s, 3H), 3.99 (s, 3H), 3.61 (t, J = 6.0 Hz, 2H), 2.59 (t, J = 7.4 Hz, 2H), 2.05 (s, 3H), 1.69 (tt, J = 6.0, 7.4 Hz, 2H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.88, 184.62, 144.69, 144.45, 142.45, 139.71, 66.03, 61.83, 61.38, 31.54, 22.56, 12.09. **S10**: ^{1}H-NMR (400 MHz, $CDCl_3$): δ 3.99 (s, 3H), 3.98 (s, 3H), 3.64 (t, J = 6.5 Hz, 2H), 2.47 (br t, J = 7.0 Hz, 2H), 2.01 (s, 3H), 1.60 (m, 2H), 1.46-1.40 (m, 4H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.85, 184.36, 144.52 (2C), 142.95, 139.04, 62.94, 61.35 (2C), 32.61, 28.67, 26.50, 26.15, 12.13; ESI-MS (*m/z*): 269.1 $[M+H]^+$. **S11**: ^{1}H-NMR (400 MHz, $CDCl_3$): δ 3.99 (s, 3H), 3.98 (s, 3H), 3.64 (t, J = 6.6 Hz, 2H), 2.45 (br t, J = 7.3 Hz, 2H), 2.01 (s, 3H), 1.56 (m, 2H), 1.44-1.27 (m, 10H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.91, 184.37, 144.51 (2C), 143.24, 138.90, 63.21, 61.35 (2C), 32.93, 29.92, 29.49, 29.45, 28.88, 26.57, 25.89, 12.11; ESI-MS (*m/z*): 311.2 $[M+H]^+$. **S12**: ^{1}H-NMR (400 MHz, $CDCl_3$): δ 3.99 (s, 3H), 3.99 (s, 3H), 2.45 (br t, J = 7.4 Hz, 2H), 2.35 (t, J = 7.5 Hz, 2H), 2.01 (s, 3H), 1.67-1.59 (m, 2H), 1.45-1.25 (m, 16H); ^{13}C-NMR (100

MHz, $CDCl_3$): δ 184.91, 184.38, 179.09, 144.51 (2C), 143.32, 138.89, 61.36 (2C), 34.06, 30.23, 29.70, 29.65, 29.58, 29.55, 29.40, 29.24, 28.94, 26.61, 24.89, 12.12; ESI-MS (*m/z*): 367.2 $[M+H]^+$.

Synthesis of ***OS-UQ2***

To a solution of **S5** (25 mg, 0.073 mmol) and **S9** (17 mg, 0.073 mmol), EDC (17 mg, 0.088 mmol) and DMAP (11 mg, 0.088 mmol) were added under N_2 atmosphere, and the mixture was stirred for 12 h at rt. The reaction was quenched with saturated aqueous NH_4Cl, extracted with CH_2Cl_2, and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 30% EtOAc/*n*-hexane) to provide **OS-UQ2** as an orange solid (32 mg, 0.056 mmol, 77%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.00 (s, 2H), 4.32 (t, J = 6.4 Hz, 2H), 4.09 (s, 3H), 3.99 (s, 3H), 3.98 (s, 3H), 3.45 (s, 6H), 2.64 (br t, J = 7.7 Hz, 2H), 2.04 (s, 3H), 1.91 (m, 2H), 1.57 (s, 12H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.52, 184.10, 165.36, 165.03, 144.59, 144.57, 141.73, 139.58, 135.05 (2C), 125.49, 117.18 (2C), 96.84 (2C), 79.41 (2C), 71.22 (2C), 64.82, 61.35 (2C), 61.21, 52.03 (2C), 28.37 (4C), 27.85, 23.29, 12.12; ESI-MS (*m/z*): 567.3 $[M+H]^+$, 589.3 $[M+Na]^+$.

Synthesis of ***OS-UQ3***

OS-UQ3 was prepared from **S5** (19 mg, 0.056 mmol) and **S10** (15 mg, 0.056 mmol) according to the same procedure described for **OS-UQ2**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20% EtOAc/*n*-hexane) to give **OS-UQ3** as an orange solid (21 mg, 0.035 mmol, 63%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.00 (s, 1H), 4.31 (t, J = 6.8 Hz, 2H), 4.08 (s, 3H), 3.99 (s, 3H), 3.99 (s, 3H), 3.45 (s, 6H), 2.49 (br t, J = 7.2 Hz, 2H), 2.02 (s, 3H), 1.80 (m, 2H), 1.57 (s, 12H), 1.48 (m, 4H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.78, 184.31, 165.32, 165.21, 144.55, 144.51, 142.75, 139.07, 135.04 (2C), 125.77, 117.13 (2C), 96.75 (2C), 79.46 (2C), 71.23 (2C), 65.30, 61.35 (2C), 61.21, 52.03 (2C), 28.68, 28.50, 28.38 (4C), 26.42, 26.33, 12.14; ESI-MS (*m/z*): 595.3 $[M+H]^+$, 617.3 $[M+Na]^+$.

Synthesis of ***OS-UQ4***

OS-UQ4 was prepared from **S5** (18 mg, 0.052 mmol) and **S11** (16 mg, 0.052 mmol) according to the same procedure described for **OS-UQ2**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20% EtOAc/*n*-hexane) to give **OS-UQ4** as an orange oil (15 mg, 0.024 mmol, 45%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.00 (s, 2H), 4.29 (t, J = 6.8 Hz, 2H), 4.08 (s, 3H), 3.99 (s, 3H), 3.99 (s, 3H), 3.45 (s, 6H), 2.45 (br t, J = 7.2 Hz, 2H), 2.01 (s, 3H), 1.76 (m, 2H), 1.57 (s, 12H), 1.45-1.22 (m, 10H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.90, 184.35, 165.29, 165.26, 144.52 (2C), 143.20, 138.90, 135.06 (2C), 125.90, 117.12 (2C), 96.72 (2C), 79.51 (2C), 71.24 (2C), 65.62, 61.35 (2C), 61.22, 52.05 (2C), 29.97, 29.44, 29.35, 28.89 (2C), 28.40 (4C), 26.57, 26.12, 12.11; ESI-MS (*m/z*): 659.3 $[M+Na]^+$.

*Synthesis of **OS-UQ5***

OS-UQ5 was prepared from **S5** (14 mg, 0.041 mmol) and **S12** (15 mg, 0.041 mmol) according to the same procedure described for **OS-UQ2**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20% EtOAc/*n*-hexane) to give **OS-UQ5** as an orange oil (18 mg, 0.026 mmol, 63%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.00 (s, 2H), 4.30 (t, J = 6.8 Hz, 2H), 4.08 (s, 3H), 3.99 (s, 3H), 3.99 (s, 3H), 3.45 (s, 6H), 2.45 (br t, J = 7.4 Hz, 2H), 2.01 (s, 3H), 1.76 (m, 2H), 1.56 (s, 12H), 1.40-1.22 (m, 18H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.92, 184.36, 165.27 (2C), 144.53, 144.51, 143.30, 138.86, 135.07 (2C), 125.93, 117.11 (2C), 96.71 (2C), 79.52 (2C), 71.24 (2C), 65.71, 61.34 (2C), 61.21, 52.04 (2C), 30.05, 29.80, 29.76, 29.72 (2C), 29.59, 29.49, 28.95, 28.91, 28.40 (4C), 26.61, 26.17, 12.11; ESI-MS (*m/z*): 731.4 $[M+K]^+$.

Syntheses of OS-UQ6−OS-UQ8

Synthesis of ***S13***

To an ice-cooled solution of *trans*, *trans*-farnesol (4.0 g, 18.0 mmol) in Et_2O (40 mL), PBr_3 (7.56 mL, 1.0 M solution of CH_2Cl_2, 7.56 mmol) was added and the mixture was stirred for 1 h at 0 ˚C. The reaction mixture was quenched with ice-cooled water, extracted with Et_2O, washed with water and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 10% EtOAc/*n*-hexane) to provide **S13** as a colorless oil (4.75 g, 16.6 mmol, 92%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.53 (tq, J = 1.2, 8.4 Hz, 1H), 5.15-5.03 (m, 2H), 4.01 (d, J = 8.4 Hz, 2H), 2.17-2.01 (m, 2H), 1.73 (d, J = 1.2 Hz, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 143.81, 135.83, 131.53, 124.52, 123.59, 120.77, 39.87, 39.72, 29.87, 26.90, 26.29, 25.90, 17.89, 16.24, 16.17.

Synthesis of ***S14***

To an ice-cooled solution of MeONa (1.26 g, 23.3 mmol) in MeOH (10 mL), ethyl acetoacetate (3.03 g, 23.3 mmol) was added. After stirring the mixture at 0 ˚C for 20 min, **S13** (4.75 g, 16.6 mmol) in dioxane (6 mL) was added and the mixture was stirred for 17 h at rt. The reaction mixture was diluted with hexane, quenched with water, extracted with Et_2O, washed with water and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 10% EtOAc/*n*-hexane) to provide **S14** as a colorless oil (1.72 g, 5.14 mmol, 31%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.18-4.98 (m, 3H), 4.18 (q, J = 7.1 Hz, 2H), 3.43 (t, J = 7.1 Hz, 1H), 2.54 (dt, J = 0.8, 7.4 Hz, 2H), 2.21 (s, 3H), 2.13-2.01 (m, 4H), 2.00-1.89 (m, 4H), 1.67 (d, J = 1.0 Hz, 3H), 1.62 (d, J = 0.5 Hz, 3H), 1.59 (s, 3H), 1.58 (s, 3H), 1.26 (t, J = 7.1 Hz, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 203.45, 169.94, 138.80, 135.53, 131.64, 124.67, 124.22, 119.98, 61.62, 60.18, 40.04, 40.02, 29.43, 27.24, 27.08, 26.84, 26.03, 18.02, 16.46, 16.32, 14.44; ESI-MS (*m/z*): 356.3 $[M+H]^+$.

Synthesis of ***S15***

To a solution of **S14** (1.72 g, 5.14 mmol) in MeOH (6 mL), 5 M aqueous KOH (3.58 mL) was added, and the mixture was heated at 80 ˚C for 2.5 h. After cooling to rt, the reaction was quenched with 1.0 M aqueous HCl. The mixture was extracted with EtOAc, washed with water, washed with saturated aqueous $NaHCO_3$, and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5% EtOAc/*n*-hexane) to provide **S15** as a colorless oil (1.01 g, 3.05 mmol, 59%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.15-4.98 (m, 3H), 2.45 (t, J = 7.6 Hz, 2H), 2.26 (q, J = 7.3 Hz, 2H), 2.13 (s, 3H), 2.11-2.01 (m, 4H), 2.01-1.89 (m, 4H), 1.68 (d, J = 1.0 Hz, 3H), 1.61 (s, 3H), 1.60 (s, 3H), 1.59 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 209.06, 136.65, 135.29, 131.50, 124.61, 124.29, 122.76, 44.01, 39.95, 39.87, 30.16, 27.00, 26.77, 25.92, 25.24, 22.71, 17.91, 16.23; ESI-MS (*m/z*): 263.2 $[M+H]^+$.

*Synthesis of **S16***

To a suspension of NaH (219 mg, 60% in mineral oil, 4.57 mmol) in anhydrous THF (11 mL) and 15-crown-5-ether (56 μL), triethylphosphono acetate (1.02 g, 4.57 mmol) was added at 0 ˚C under N_2 atmosphere and the mixture was stirred for 15 min. Then the mixture was allowed to cool to -30 ˚C, and a solution of **S15** (1.01 g, 3.05 mmol) in THF (10 mL) was added, and the mixture was warmed to rt. After stirring for 40 h, the reaction was quenched with water, extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 2-5% EtOAc/*n*-hexane) to provide **S16** as a colorless oil (982 mg, 2.95 mmol, 97%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.66 (d, J = 0.9 Hz, 1H), 5.17-5.04 (m, 3H), 4.14 (q, J = 7.1 Hz, 2H), 2.22-2.14 (m, 7H), 2.14-2.02 (m, 4H), 2.02-1.93 (m, 4H), 1.67 (d, J = 0.9 Hz, 3H), 1.60 (s, 9H), 1.27 (t, J = 7.1 Hz, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 167.12, 159.97, 136.39, 135.27, 131.48, 124.62, 124.34, 123.14, 115.87, 59.67, 41.21, 39.94, 39.90, 27.00, 26.83, 26.23, 25.92, 19.04, 17.91, 16.26, 16.22, 14.57; ESI-MS (*m/z*): 333.2 $[M+H]^+$.

*Synthesis of **S17***

To a solution of **S16** (982 mg, 2.95 mmol) in anhydrous Et_2O (10 mL), DIBAL-H (8.6 mL, 1.0 M solution of hexane, 8.6 mmol) was added at -78 ˚C under N_2 atmosphere, and the mixture was stirred for 50 min. The reaction was quenched with saturated aqueous potassium sodium tartrate solution, extracted with Et_2O, washed with brine and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5-10% EtOAc/*n*-hexane) to provide **S17** as a colorless oil (659 mg, 2.27 mmol, 97%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.42 (tq, J = 1.2, 5.8 Hz, 1H), 5.17-5.03 (m, 3H), 4.15 (d, J = 8.0 Hz, 2H), 2.16-2.01 (m, 8H), 2.01-1.94 (m, 4H), 1.68 (s, 6H), 1.58 (s, 9H), 1.14 (s, 1H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 140.05, 135.61, 135.19, 131.49, 124.60, 124.39, 124.00, 123.52, 59.62, 39.94, 39.90, 39.77, 26.98, 26.84, 26.54, 25.90, 17.89, 16.49, 16.23, 16.22.

*Synthesis of **S18***

To a solution of **S17** (618 mg, 2.13 mmol) in CH_2Cl_2 (15 mL), Et_3N (593 μL, 4.23 mmol), Ac_2O (301 mg, 3.19 mmol) and DMAP (26 mg, 0.21 mmol) was added, and the mixture was stirred for 3 h at rt. The reaction was quenched with saturated aqueous NH_4Cl, extracted with CH_2CH_2 and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5% EtOAc/*n*-hexane) to provide **S18** as a colorless oil (663 mg, 1.99 mmol, 94%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (tq, J = 1.2, 7.1 Hz, 1H), 5.16-5.06 (m, 3H), 4.59 (d, J = 7.1 Hz, 2H), 2.16-2.02 (m, 8H), 2.05 (s, 3H), 2.02-1.94 (m, 4H), 1.71 (s, 6H), 1.68 (s, 9H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.33, 142.49, 135.71,

135.18, 131.47, 124.60, 124.39, 123.83, 118.47, 61.61, 39.93, 39.90, 39.76, 26.98, 26.84, 26.42, 25.90, 21.26, 17.89, 16.68, 16.24, 16.21.

*Synthesis of **S19***

To an ice-cooled solution of **S18** (663 mg, 1.99 mmol) in a mixture of THF (8 mL) and H_2O (4 mL), NBS (390 mg, 2.19 mmol) was added in several small portions over 1 h and the mixture was stirred for 1.5 h at 0 ˚C. The reaction mixture was diluted with water, extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15% EtOAc/*n*-hexane) to provide **S19** as a colorless oil (492 mg, 1.15 mmol, 58%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.35 (tq, J = 1.2, 7.1 Hz, 1H), 5.20 (t, J = 6.9 Hz, 1H), 5.10 (t, J = 6.9 Hz, 1H), 4.58 (d, J = 7.1 Hz, 2H), 3.97 (dd, J = 1.9, 11.3 Hz, 1H), 2.32 (m, 1H), 2.15-2.03 (m, 8H), 2.05 (s, 3H), 2.02-1.93 (m, 2H), 1.84-1.73 (m, 2H), 1.71 (s, 3H), 1.60 (s, 6H), 1.35 (s, 3H), 1.33 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.34, 142.47, 135.47, 133.24, 126.14, 124.02, 118.48, 72.65, 71.10, 61.61, 39.79, 39.74, 38.37, 32.34, 26.82, 26.78, 26.40, 26.03, 21.26, 16.68, 16.20, 16.04; ESI-MS (*m/z*): 451.2/453.2 $[M+Na]^+$.

*Synthesis of **S20***

To an ice-cooled solution of **S19** (487 mg, 1.15 mmol) in THF (8 mL), NaH (110 mg, 60% in mineral oil, 2.27 mmol) was added under N_2 atmosphere, and the mixture was stirred for 13 h. The reaction was quenched with saturated aqueous NH_4Cl, extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15% EtOAc/*n*-hexane) to provide **S20** as a colorless oil (346 mg, 0.99 mmol, 87%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (t, J = 7.1 Hz, 1H), 5.15 (t, J = 6.8 Hz, 1H), 5.10 (t, J = 6.6 Hz, 1H), 4.58 (d, J = 7.1 Hz, 2H), 2.70 (t, J = 6.2 Hz, 1H), 2.10-2.02 (m, 8H), 2.05 (s, 3H), 2.01-1.95 (m, 2H), 1.70 (s, 3H), 1.63 (m, 2H), 1.62 (s, 3H), 1.60 (s, 3H), 1.30 (s, 3H), 1.26 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.33, 142.46, 135.58, 134.28, 125.04, 123.92, 118.48, 64.39, 61.61, 58.51, 39.83, 39.74, 36.52, 27.69, 26.85, 26.42, 25.12, 21.27, 18.96, 16.69, 16.23, 16.21; ESI-MS (*m/z*): 349.2 $[M+H]^+$, 371.2 $[M+Na]^+$.

*Synthesis of **S21***

To an ice-cooled solution of **S20** (346 mg, 0.99 mmol) in THF (2 mL), a solution of $NaIO_4$ (428 mg, 1.99 mmol) in H_2O (3 mL) and H_5IO_6 (113 mg, 0.50 mmol) in THF (5 mL) were added dropwise, and the mixture was stirred for 1 h. Then, the mixture was allowed to warm to rt, followed by stirring for further 3 h. The reaction was quenched with 1.0 M aqueous HCl, extracted with EtOAc, washed with saturated aqueous $NaHCO_3$ and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 10% EtOAc/*n*-hexane) to provide **S21** as a colorless oil (235 mg, 0.77

mmol, 77%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 9.75 (s, 1H), 5.34 (t, J = 7.1 Hz, 1H), 5.14 (t, J = 6.8 Hz, 1H), 5.09 (t, J = 6.6 Hz, 1H), 4.59 (d, J = 7.1 Hz, 2H), 2.50 (m, 2H), 2.31 (t, J = 7.4 Hz, 2H), 2.14-2.02 (m, 6H), 2.05 (s, 3H), 1.97 (m, 2H), 1.71 (s, 3H), 1.61 (s, 3H), 1.59 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 202.85, 171.31, 142.42, 135.38, 133.12, 125.55, 124.05, 118.49, 61.58, 42.33, 39.70, 39.66, 32.05, 27.72, 26.38, 21.24, 16.66, 16.28, 16.18.

Synthesis of ***S22***

To a solution of **S21** (231 mg, 0.75 mmol) in MeOH (10 mL), $NaBH_4$ (34 mg, 1.10 mmol) was added in several portions at -10 ˚C. After stirring for 3 h at -10 ˚C, the reaction was quenched with saturated aqueous NH_4Cl and concentrated *in vacuo* to remove MeOH. The residue was extracted with EtOAc and dried over anhydrous Na_2SO_4. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20% EtOAc/*n*-hexane) to provide **S22** as a colorless oil (189 mg, 0.61 mmol, 81%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (t, J = 7.1 Hz, 1H), 5.14 (t, J = 6.8 Hz, 1H), 5.09 (t, J = 6.6 Hz, 1H), 4.58 (d, J = 7.1 Hz, 2H), 3.62 (t, J = 6.4 Hz, 2H), 2.14-2.01 (m, 8H), 2.05 (s, 3H), 2.00-1.95 (m, 2H), 1.70 (s, 3H), 1.66 (m, 2H), 1.61 (s, 3H), 1.59 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.34, 142.44, 135.49, 134.83, 124.86, 123.92, 118.44, 62.96, 61.58, 39.76, 39.67, 36.18, 30.93, 26.66, 26.32, 21.22, 16.63, 16.15, 16.03; ESI-MS (*m/z*): 316.2 $[M+H]^+$, 331.2 $[M+Na]^+$.

Synthesis of ***S23***

To an ice-cooled solution of **S22** (189 mg, 0.61 mmol) in CH_2Cl_2 (5 mL), imidazole (61 mg, 0.90 mmol), DMAP (4 mg, 0.03 mmol), and TBS-Cl (101 mg, 0.66 mmol) was added, and the mixture was stirred for 1.5 h. The reaction was quenched with water, extracted with CH_2Cl_2 and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5% EtOAc/*n*-hexane) to provide **S23** as a colorless oil (253 mg, 0.60 mmol, 98%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (tq, J = 1.2, 7.2 Hz, 1H), 5.14-5.07 (m, 2H), 4.59 (d, J = 7.1 Hz, 2H), 3.58 (t, J = 6.6 Hz, 2H), 2.15-2.02 (m, 6H), 2.05 (s, 3H), 2.00-1.95 (m, 4H), 1.71 (s, 3H), 1.63 (m, 2H), 1.59 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.33, 142.50, 135.69, 134.91, 124.44, 123.84, 118.47, 63.14, 61.62, 39.90, 39.76, 36.01, 31.43, 26.85, 26.43, 26.19 (3C), 21.17, 18.57, 16.69, 16.24, 16.19, -5.04 (2C); ESI-MS (*m/z*): 423.3 $[M+H]^+$, 445.3 $[M+Na]^+$.

Synthesis of ***S24***

To a solution of **S23** (253 mg, 0.60 mmol) in MeOH (4 mL), K_2CO_3 (41 mg, 0.30 mmol) was added, and the mixture was stirred for 1.5 h. The reaction was quenched with saturated aqueous NH_4Cl and concentrated *in vacuo* to remove MeOH. The residue was purified by silica gel column chromatography

(Wako gel® C-200, 15% EtOAc/*n*-hexane) to provide **S24** as a colorless oil (182 mg, 0.48 mmol, 80%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.42 (tq, J = 1.2, 8.2 Hz, 1H), 5.14-5.08 (m, 2H), 4.15 (d, J = 6.9 Hz, 2H), 3.58 (t, J = 6.6 Hz, 2H), 2.15-1.95 (m, 10H), 1.68 (s, 3H), 1.62 (m, 2H), 1.60 (s, 3H), 1.59 (s, 3H), 0.90 (s, 9H), 0.05 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 139.97, 135.56, 134.90, 124.43, 124.01, 123.58, 63.17, 59.61, 39.89, 39.76, 36.00, 31.41, 26.82, 26.52, 26.19 (3C), 18.57, 16.50, 16.23, 16.21, -5.04 (2C); ESI-MS (*m/z*): 381.3 $[M+H]^+$, 403.3 $[M+Na]^+$.

*Synthesis of **S25***

S25 was synthesized in 4 steps according to the procedures described in *ref. 8* using commercially available *trans,trans*-farnesyl acetate as a starting material: ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (tq, J = 1.3, 7.1 Hz, 1H), 5.13 (tq, J = 1.2, 6.8 Hz, 1H), 4.59 (d, J = 7.1 Hz, 2H), 3.62 (t, J = 6.5 Hz, 2H), 2.13 (td, J = 7.0, 7.1 Hz, 2H), 2.08-2.04 (m, 7H), 1.70 (d, J = 1.0 Hz, 3H), 1.69-1.63 (m, 2H), 1.61 (s, 3H); ^{13}C-NMR (100 MHz, CDCl3): δ 171.38, 142.22, 135.32, 124.34, 118.68, 62.87, 61.62, 39.62, 36.09, 30.86, 26.22, 21.26, 16.60, 16.09.

*Synthesis of **S26***

To a solution of **S25** (248 mg, 1.03 mmol) in anhydrous DMF (5 mL), imidazole (105 mg, 1.55 mmol) and TBDPS-Cl (426 mg, 1.55 mmol) were added, and the mixture was stirred for 2 h at rt. To complete the reaction, additional TBDPS-Cl (426 mg, 1.55 mmol) was added to the mixture, and the reaction was left for a further 15 h at rt. The reaction was quenched with saturated aqueous NH_4Cl, extracted with Et_2O and dried over anhydrous $MgSO_4$. The organic layer was concentrated *in vacuo* giving a colorless oil. The resulting mixture was dissolved in MeOH (6 mL). Then K_2CO_3 (214 mg, 1.55 mmol) was added to the solution at rt. After stirring for 1.5 h, the mixture was concentrated *in vacuo* to remove MeOH. The crude product was diluted with saturated aqueous NH_4Cl, extracted with EtOAc and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15% EtOAc/*n*-hexane) to provide **S26** as a colorless oil (410 mg, 0.94 mmol, 91%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.68-7.65 (m, 4H), 7.44-7.35 (m, 6H), 5.39 (tq, J = 1.2, 7.0 Hz, 1H), 5.09 (t, J = 6.9 Hz, 1H), 4.13 (m, 2H), 3.64 (t, J = 6.5 Hz, 2H), 2.12-1.98 (m, 6H), 1.69-1.61 (m, 2H), 1.67 (s, 3H), 1.56 (s, 3H), 1.05 (s, 9H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 140.02, 135.79 (4C), 135.29, 134.35 (2C), 129.71 (2C), 127.79 (4C), 124.09, 123.54, 63.78, 59.63, 39.73, 35.98, 31.13, 27.08 (3C), 26.52, 19.44, 16.50, 16.17; ESI-MS (*m/z*): 459.2 $[M+Na]^+$.

*Synthesis of **S27***

To an ice-cooled solution of **S26** (410 mg, 0.94 mmol) and Et_3N (524 μL) in THF (7 mL), MsCl (323 mg, 2.82 mmol) was added. After stirring for 30 min, LiBr (815 mg, 9.39 mmol) was added, and the mixture was stirred for 1 h at 0 ˚C. The reaction was quenched with saturated aqueous $NaHCO_3$, extracted with Et_2O and dried over anhydrous $MgSO_4$. The organic layer was concentrated *in vacuo*, providing a colorless oil.

The residue was dissolved in DMF (5 mL), then, sodium benzenesulfinate dihydrate (566 mg, 2.82 mmol) was added to the mixture at 0 ˚C, followed by the stirring for 2 h. After the mixture was stirred for 12 h at rt, the reaction was quenched with saturated aqueous NH_4Cl, extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15% EtOAc/*n*-hexane) to provide **S27** as a colorless oil (439 mg, 0.78 mmol, 83%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.86 (m, 2H), 7.68-7.65 (m, 4H), 7.60 (m, 1H), 7.52-7.47 (m, 2H), 7.43-7.33 (m, 6H), 5.17 (t, J = 7.9 Hz, 1H), 5.03 (m, 1H), 3.78 (d, J = 7.9 Hz, 2H), 3.64 (t, J = 6.3 Hz, 2H), 2.05 (t, J = 7.6 Hz, 2H), 2.00-1.96 (m, 4H), 1.65 (m, 2H), 1.55 (s, 3H), 1.29 (s, 3H), 1.05 (s, 9H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 146.49, 138.80, 135.67 (4C), 135.48, 134.18 (2C), 133.62, 129.65 (2C), 129.05 (2C), 128.66 (2C), 127.71 (4C), 123.56, 110.43, 63.64, 56.18, 39.78, 35.89, 30.98, 27.00 (3C), 26.29, 19.33, 16.28, 16.06; ESI-MS (*m/z*): 561.2 $[M+H]^+$, 583.2 $[M+Na]^+$.

Synthesis of ***S28***

To an ice-cooled solution of *trans*, *trans*-farnesyl acetate (1.0 g, 3.78 mmol) in CH_2Cl_2 (4 mL), salicylic acid (52 mg, 0.38 mmol), SeO_2 (42 mg, 0.38 mmol), and 70% aqueous *tert*-butyl hydroperoxide solution (1.54 mL, 11.3 mmol) were added, and the mixture was stirred for 3 days. The reaction mixture was diluted with toluene, then concentrated *in vacuo*. The residue was diluted with Et_2O, washed with saturated aqueous $NaHCO_3$ and dried over anhydrous $MgSO_4$. The organic layer was concentrated *in vacuo* giving a yellow oil. The residue containing alcohol and aldehyde was dissolved in MeOH (10 mL), and then $NaBH_4$ (214 mg, 5.67 mmol) was added to the mixture in several portions. After stirring for 8 h at 0 ˚C, the reaction mixture was diluted with saturated aqueous NH_4Cl, extracted with EtOAc and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5-20% EtOAc/*n*-hexane) to provide unreacted material (250 mg, 0.95 mmol, 25%) and **S28** as a colorless oil (223 mg, 0.80 mmol, 21%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.40-5.31 (m, 2H), 5.10 (t, J = 6.3 Hz, 1H), 4.58 (d, J = 7.1 Hz, 2H), 3.98 (s, 2H), 2.15-1.98 (m, 8H), 2.05 (s, 3H), 1.70 (s, 3H), 1.66 (s, 3H), 1.60 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.38, 142.40, 135.30, 134.96, 126.16, 124.11, 118.52, 69.18, 61.61, 39.68, 26.37, 26.34, 21.26, 16.66, 16.20, 13.89.

Synthesis of ***S29***

To an ice-cooled solution of **S28** (223 mg, 0.80 mmol) and Et_3N (445 μL) in THF (5 mL), MsCl (275 mg, 2.40 mmol) was added, followed by the stirring for 10 min. Then, LiBr (694 mg, 8.0 mmol) was added to the mixture at 0 ˚C, and the stirring was continued for 2 h. The reaction was quenched with saturated aqueous NH_4Cl, extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5% EtOAc/*n*-hexane) to provide **S29** as a colorless oil (252 mg, 0.73 mmol, 92%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.57 (t, J = 6.9 Hz, 1H), 5.34 (tq, J = 1.2, 7.1 Hz, 1H), 5.10 (t, J = 6.8 Hz, 1H), 4.59 (d, J = 7.1 Hz, 2H), 3.97 (s, 2H), 2.15-1.98 (m, 8H), 2.05 (s, 3H), 1.75 (s, 3H), 1.70 (s, 3H), 1.60 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.29, 142.32, 134.83, 132.14, 131.34, 124.43, 118.52, 61.57, 41.99, 39.63, 38.91, 27.00, 26.33, 21.24, 16.65, 16.15, 14.83.

Synthesis of ***S30***

To an ice-cooled solution of **S27** (245 mg, 0.44 mmol) and **S29** (150 mg, 0.44 mmol) in DMF (10 mL), NaH (53 mg, 60% in mineral oil, 1.31mmol) was added under N_2 atmosphere, and stirred for 12 h at 0 ˚C. To complete the reaction, additional NaH (10 mg, 60% in mineral oil, 0.25 mmol) was added, and the reaction was left for further 4 h at rt with vigorous stirring. The reaction was quenched with saturated aqueous NH_4Cl, extracted with Et_2O and dried over anhydrous $MgSO_4$. The organic layer was concentrated *in vacuo*, providing a yellow oil. The residue was dissolved in MeOH (7 mL), followed by the addition of K_2CO_3 (91 mg, 0.66 mmol). After stirring for 1 h, the mixture was concentrated *in vacuo* to remove MeOH. The residue was diluted with saturated aqueous NH_4Cl, extracted with EtOAc, and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20-30% EtOAc/*n*-hexane) to provide **S30** as a little yellow oil (176 mg, 0.23 mmol, 52%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.84 (m, 2H), 7.67 (m, 4H), 7.60 (m, 1H), 7.50 (m, 2H), 7.44-7.34 (m, 6H), 5.40 (tq, J = 1.2, 6.9 Hz, 1H), 5.15 (t, J = 6.7 Hz, 1H), 5.09-5.01 (m, 2H), 4.90 (d, J = 10.3 Hz, 1H), 4.15 (d, J = 6.9 Hz, 2H), 3.88 (m, 1H), 3.63 (t, J = 6.5 Hz, 2H), 2.88 (d, J = 13.2 Hz, 1H), 2.29 (dd, J = 11.6, 13.2 Hz, 1H), 2.13-1.99 (m, 8H), 1.94-1.86 (m, 6H), 1.67 (s, 3H), 1.56 (s, 3H), 1.55 (s, 3H), 1.52 (s, 3H), 1.15 (d, J = 3.0 Hz, 3H), 1.05 (s, 9H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 145.21, 139.62, 138.18, 135.73 (4C), 135.49, 135.13, 134.25 (2C), 133.51, 129.96, 129.69 (2C), 129.41 (2C), 128.85 (2C), 128.42, 127.75 (4C), 124.19, 123.75, 123.66, 117.44, 63.75, 59.53, 39.91, 39.68, 39.53, 37.48, 35.96, 31.07, 27.05 (3C), 26.80, 26.63, 26.43, 19.39, 16.54, 16.46, 16.14 (2C), 16.09; ESI-MS (*m/z*): 803.4 $[M+Na]^+$.

Synthesis of ***S31***

To an ice-cooled solution of **S30** (20 mg, 0.026 mmol) in THF (3 mL), $LiBHEt_3$ (1.0 M solution in THF, 380 μL, 0.384 mmol) was added dropwise under N_2 atmosphere, followed by the stirring for 10 min at 0 ˚C.

Then, $Pd(dppp)Cl_2$ (2 mg, 0.002 mmol) was added to the mixture, and stirred for 1 h at 0 ˚C. The reaction mixture was diluted with CH_2Cl_2, and quenched by the careful addition of saturated aqueous NH_4Cl. The mixture was extracted with CH_2Cl_2 and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 10% EtOAc/*n*-hexane) to provide **S31** as a colorless oil (11 mg, 0.017 mmol, 66%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.67 (m, 4H), 7.44-7.34 (m, 6H), 5.42 (tq, J = 1.2, 6.9 Hz, 1H), 5.14-5.06 (m, 4H), 4.15 (d, J = 6.8 Hz, 2H), 3.64 (t, J = 6.5 Hz, 2H), 2.15-1.93 (m, 18H), 1.68 (s, 3H), 1.65 (m, 2H), 1.60 (s, 9H), 1.56 (s, 3H), 1.05 (s, 9H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 139.92, 135.77 (4C), 135.59, 135.21, 135.13, 134.79, 134.34 (2C), 129.68 (2C), 127.76 (4C), 124.58, 124.43, 124.37, 123.97, 123.58, 63.80, 59.57, 39.92 (3C), 39.77, 35.98, 31.16, 27.07 (3C), 26.91 (2C), 26.87, 26.53, 19.42, 16.48, 16.22 (3C), 16.13; ESI-MS (*m/z*): 663.4 $[M+Na]^+$.

*Synthesis of **S32***

To a solution of solanesol (1.50 g, 2.38 mmol) in CH_2Cl_2 (15 mL), Et_3N (650 μL, 4.75 mmol), Ac_2O (365 mg, 3.57 mmol), and DMAP (29 mg, 0.24 mmol) were added, and the mixture was stirred for 3 h at rt. The reaction mixture was quenched with saturated aqueous NH_4Cl, extracted with CH_2Cl_2 and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5% EtOAc/*n*-hexane) to provide **S32** as a colorless oil (1.54 g, 22.8 mmol, 96%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (tq, J = 1.2, 7.1 Hz, 1H), 5.13-5.07 (m, 8H), 4.54 (d, J = 7.1 Hz, 2H), 2.13-2.04 (m, 18H), 2.05 (s, 3H), 2.00-1.96 (m, 14H), 1.70 (s, 3H), 1.68 (s, 3H), 1.60 (s, 24H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.34, 142.52, 135.75, 135.24, 135.16 (5C), 131.47, 124.63, 124.49 (5C), 124.39, 123.82, 118.46, 61.63, 39.97 (7C), 39.77, 27.00, 26.94, 26.90 (6C), 26.44, 25.91, 21.27, 17.90, 16.70, 16.25 (6C); ESI-MS (*m/z*): 673.6 $[M+H]^+$, 695.5 $[M+Na]^+$.

*Synthesis of **S33***

To an ice-cooled solution of **S32** (1.40 g, 2.08 mmol) in a mixture of THF (50 mL) and H_2O (25 mL), NBS (423 mg, 2.38 mmol) was added carefully in several portions over 1 h. After stirring for 4 h at 0 ˚C, the reaction mixture was diluted with water, extracted with EtOAc, and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5-15% EtOAc/*n*-hexane) to provide **S33** as a colorless oil (707 mg, 1.05 mmol, 50%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (tq, J = 1.2, 7.1 Hz, 1H), 5.20 (m, 1H), 5.14-5.08 (m, 6H), 4.58 (d, J = 7.1 Hz, 2H), 3.98 (dd, J = 1.9, 11.4 Hz, 1H), 2.15-2.03 (m, 18H), 2.05 (s, 3H), 2.01-1.93 (m, 12H), 1.84-1.75 (m, 2H), 1.70 (s, 3H), 1.60 (s, 21H), 1.34 (s, 3H), 1.33 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.34, 142.51, 135.74, 135.23, 135.16 (2C), 135.12, 134.90, 133.18, 126.23, 124.68, 124.50, 124.47 (2C), 124.38, 123.81, 118.45, 72.66, 71.20,

61.62, 39.96 (5C), 39.83, 39.76, 38.39, 32.38, 26.94 (4C), 26.89, 26.86 (2C), 26.43, 25.99, 21.27, 16.69, 16.25 (5C), 16.20, 16.07; ESI-MS (*m/z*): 791.5/793.5 $[M+Na]^+$.

Synthesis of ***S34***

To a suspension of NaH (61 mg, 60% in mineral oil, 1.53 mmol) in anhydrous THF (25 mL), a solution of **S33** (786 mg, 1.02 mmol) in THF (5 mL) was added at 0 ˚C. Then, the mixture was allowed to warm to rt, and stirred for 18 h. The reaction mixture was quenched with saturated aqueous NH_4Cl, extracted with Et_2O, washed with brine and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5-10% EtOAc/*n*-hexane) to provide **S34** as a colorless oil (504 mg, 0.73 mmol, 72%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (tq, J = 1.2, 7.1 Hz, 1H), 5.16 (m, 1H), 5.15-5.08 (m, 6H), 4.59 (d, J = 7.1 Hz, 2H), 2.70 (t, J = 6.3 Hz, 2H), 2.14-2.05 (m, 18H), 2.06 (s, 3H), 2.00-1.95 (m, 12H), 1.70 (s, 3H), 1.69-1.60 (m, 2H), 1.62 (s, 3H), 1.60 (s, 18H), 1.30 (s, 3H), 1.26 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.34, 142.51, 135.75, 135.24, 135.18, 135.16, 135.13, 135.00, 134.20, 125.15, 124.59, 124.49, 124.48, 124.46, 124.39, 123.81, 118.47, 64.43, 61.62, 58.53, 39.97 (5C), 39.87, 39.77, 36.53, 27.70, 26.94 (5C), 26.90, 26.44, 25.12, 21.27, 18.97, 16.70, 16.25 (7C); ESI-MS (*m/z*): 711.6 $[M+Na]^+$

Synthesis of ***S35***

To an ice-cooled solution of **S34** (504 mg, 0.73 mmol) in THF (45 mL), $NaIO_4$ (312 mg, 1.46 mmol) in H_2O (15 mL) and H_5IO_6 (84 mg, 0.37 mmol) in THF (15 mL) were added dropwise. The mixture was allowed to warm to rt, followed by vigorous stirring for 19 h. The reaction was quenched with saturated aqueous NH_4Cl, extracted with EtOAc and dried over anhydrous $MgSO_4$. The organic layer was concentrated *in vacuo*, giving the desired aldehyde as a colorless oil.

To a solution of the aldehyde in MeOH (50 mL), $NaBH_4$ (42 mg, 1.10 mmol) was added in several portions at 0 ˚C, and the mixture was allowed to warm to rt. After stirring for 3 h, the reaction was quenched with saturated aqueous NH_4Cl, extracted with EtOAc and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15% EtOAc/*n*-hexane) to provide **S35** as a white solid (220 mg, 0.34 mmol, 46%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (tq, J = 1.2, 7.1 Hz, 1H), 5.15 (tq, J = 1.2, 6.7 Hz, 1H), 5.14-5.10 (m, 6H), 4.59 (d, J = 7.1 Hz, 2H), 3.63 (t, J = 6.4 Hz, 2H), 2.13-2.03 (m, 18H), 2.05 (s, 3H), 2.00-1.94 (m, 12H), 1.70 (s, 3H), 1.69-1.63 (m, 2H), 1.61 (s, 3H), 1.60 (s, 18H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.35, 142.51, 135.73, 135.22, 135.15 (2C), 135.13, 134.97, 134.79, 125.04, 124.62, 124.49, 124.47, 124.45, 124.38, 123.81, 118.44, 63.04, 61.62, 39.96 (3C), 39.93 (2C), 39.85, 39.76, 36.22, 30.94, 26.92 (4C), 26.88, 26.80, 26.43, 21.26, 16.69, 16.24 (5C), 16.19, 16.07.

Synthesis of ***S36***

To an ice-cooled solution of **S35** (180 mg, 0.28 mmol), Et_3N (80 μL), and DMAP (4 mg, 0.03 mmol) in anhydrous CH_2Cl_2 (5 mL), TBS-Cl (63 mg, 0.42 mmol) was added, and the mixture was allowed to warm to rt. After stirring for 6 h, the reaction mixture was concentrated *in vacuo* and the residue was purified by silica gel column chromatography (Wako gel® C-200, 5% EtOAc/*n*-hexane) to provide **S36** as a colorless oil (193 mg, 0.25 mmol, 90%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.34 (tq, J = 1.2, 7.1 Hz, 1H), 5.13-5.09 (m, 7H), 4.58 (d, J = 7.1 Hz, 2H), 3.58 (t, J = 6.6 Hz, 2H), 2.13-2.04 (m, 16H), 2.05 (s, 3H), 2.03-1.96 (m, 14H), 1.70 (s, 3H), 1.65-1.58 (m, 2H), 1.60 (s, 21H), 0.89 (s, 9H), 0.04 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 171.35, 142.52, 135.75, 135.24, 135.17 (3C), 135.13, 134.83, 124.55, 124.48 (4C), 124.39, 123.82, 118.46, 63.16, 61.63, 39.97 (4C), 39.95 (2C), 39.77, 36.02, 31.43, 26.95 (4C), 26.91 (2C), 26.45, 26.20 (3C), 21.27, 18.58, 16.70, 16.25 (6C), 16.20, -5.03 (2C); ESI-MS (*m/z*): 785.6 $[M+Na]^+$.

*Synthesis of **S37***

To a solution of **S36** (218 mg, 0.28 mmol) in MeOH (20 mL), K_2CO_3 (78 mg, 0.57 mmol) was added in one portion, and the mixture was stirred for 3.5 h. The reaction was quenched with saturated aqueous NH_4Cl at 0 ˚C, extracted with Et_2O and dried over anhydrous Na_2SO_4. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15% EtOAc/*n*-hexane) to provide **S37** as a white solid (173 mg, 0.24 mmol, 86%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.42 (tq, J = 1.2, 6.9 Hz, 1H), 5.14-5.09 (m, 7H), 4.15 (d, J = 6.9 Hz, 2H), 3.58 (t, J = 6.6 Hz, 2H), 2.13-2.04 (m, 16H), 2.02-1.95 (m, 14H), 1.68 (s, 3H), 1.63-1.58 (m, 2H), 1.60 (s, 21H), 0.89 (s, 9H), 0.05 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 140.06, 135.63, 135.23, 135.16 (3C), 135.11, 134.82, 124.54, 124.47 (4C), 124.38, 123.97, 123.54, 63.15, 59.63, 39.96 (4C), 39.94 (2C), 39.78, 36.01, 31.41, 26.93 (4C), 26.90 (2C), 26.55, 26.20 (3C), 18.57, 16.51, 16.25 (6C), 16.19, -5.03 (2C); ESI-MS (*m/z*): 743.5 $[M+Na]^+$.

*Synthesis of **S38***

To a solution of **S24** (182 mg, 0.48 mmol) and Et_3N (334 μL, 2.3 mmol) in THF (4 mL), MsCl (164 mg, 1.43 mmol) was added at -20 ˚C. After stirring for 30 min at -20 ˚C, LiBr (415 mg, 4.78 mmol) was added and the reaction mixture was allowed to warm to 0 ˚C, followed by vigorous stirring for 2 h. The reaction was quenched with saturated aqueous $NaHCO_3$, extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 10% EtOAc/*n*-hexane) to provide **S38** as a colorless oil (152 mg, 0.34 mmol, 72%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.53 (tq, J = 1.2, 8.4 Hz, 1H), 5.13-5.05 (m, 2H), 4.02 (d, J = 8.4 Hz, 2H), 3.58 (t, J = 6.6 Hz, 2H), 2.13-2.03 (m, 6H), 2.02-1.94 (m, 4H), 1.73 (d, J = 1.3 Hz, 3H), 1.61 (m, 2H), 1.60 (s, 6H), 0.90 (s, 9H), 0.05 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 143.82, 135.84, 134.91, 124.43, 123.60, 120.76, 63.14, 39.87, 39.74, 36.01, 31.42, 26.81, 26.32, 26.19 (3C), 18.56, 16.27, 16.20 (2C), -5.04 (2C).

*Synthesis of **S39***

S39 was prepared from **S31** (28 mg, 0.043 mmol) according to the same procedure described for **S38**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5% EtOAc/*n*-hexane) to provide **S39** as a colorless oil (26 mg, 0.037 mmol, 86%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.67 (m, 4H), 7.44-7.34 (m, 6H), 5.53 (tq, J = 1.0, 8.4 Hz, 1H), 5.13-5.06 (m, 4H), 4.01 (d, J = 8.4 Hz, 2H), 3.64 (t, J = 6.5 Hz, 2H), 2.14-1.92 (m, 18H), 1.72 (d, J = 1.0 Hz, 3H), 1.65 (m, 2H), 1.59 (s, 9H), 1.56 (s, 3H), 1.05 (s, 9H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 143.83, 135.89, 135.79 (4C), 135.23, 135.16, 134.81, 134.37 (2C), 129.69 (2C), 127.78 (4C), 124.59, 124.44, 124.38, 123.59, 120.77, 63.82, 39.96 (2C), 39.91, 39.75, 36.01, 31.19, 29.88, 27.09 (3C), 26.94 (2C), 26.86, 26.33, 19.44, 16.29, 16.26 (2C), 16.20, 16.16.

*Synthesis of **S40***

S40 was prepared from **S37** (173 mg, 0.24 mmol) according to the same procedure described for **S38**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 2.5% EtOAc/*n*-hexane) to provide **S40** as a colorless oil (186 mg, 0.23 mmol, 96%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.53 (tq, J = 1.2, 8.4 Hz, 1H), 5.13-5.07 (m, 7H), 4.02 (d, J = 8.4 Hz, 2H), 3.58 (t, J = 6.6 Hz, 2H), 2.13-2.04 (m, 16H), 2.02-1.95 (m, 14H), 1.73 (d, J = 1.2 Hz, 3H), 1.63-1.58 (m, 2H), 1.60 (s, 21H), 0.89 (s, 9H), 0.04 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 143.84, 135.89, 135.24, 135.16 (3C), 135.12, 134.83, 124.55, 124.50, 124.48 (2C), 124.46, 124.38, 123.59, 120.77, 63.15, 39.97 (4C), 39.92, 39.76, 36.02, 31.81, 31.43, 29.88, 26.94 (4C), 26.86, 26.33, 26.20 (3C), 22.88, 18.57, 16.29, 16.25 (4C), 16.20 (2C), 14.34, -5.03 (2C).

*Synthesis of **S41***

Diels-Alder cycloadduct **S41** was prepared according to the procedure described in *ref. 9* using commercially available 2,3-dimethoxy-5-methyl-1,4-benzoquinone and freshly distilled cyclopentadiene; ^{1}H-NMR (400 MHz, $CDCl_3$): δ 6.16 (m, 1H), 6.02 (m, 1H), 3.94 (s, 3H), 3.93 (s, 3H), 3.43 (s, 1H), 3.09 (s, 1H), 2.84 (d, J = 3.1 Hz, 2H), 1.67 (d, J = 7.3 Hz, 1H), 1.55 (d, J = 7.3 Hz, 1H), 1.49 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 198.64, 195.05, 150.78, 150,72, 138.34, 134.69, 60.83 (2C), 57.26, 53.59, 52.74, 49.02, 46.52, 26.70; ESI-MS (*m/z*): 249.1 $[M+H]^+$.

*Synthesis of **S42***

To a solution of **S41** (111 mg, 0.45 mmol) in a mixture of anhydrous THF (2 mL) and DMF (6 mL), *t*-BuOK (77 mg, 0.69 mmol) was added at -40 ˚C under N_2 atmosphere, followed by stirring for 5 min at -40 ˚C. Then, **S38** (186 mg, 0.23 mmol) in THF (3 mL) was carefully added to the mixture, and stirred for 2 h at 0 ˚C. The reaction mixture was quenched with saturated aqueous NH_4Cl, extracted with Et_2O, and

dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 10% EtOAc/*n*-hexane) to provide **S42** as a yellow oil (143 mg, 0.23 mmol, 68%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 6.06 (m, 2H), 5.13-5.05 (m, 3H), 3.90 (s, 3H), 3.88 (s, 3H), 3.57 (t, J = 6.6 Hz, 2H), 3.10 (br s, 1H), 3.01 (br s, 1H), 2.75 (dd, J = 7.4, 15.1 Hz, 1H), 2.42 (dd, J = 6.3, 15.1 Hz, 1H), 2.08-1.93 (m, 10H), 1.79 (d, J = 9.4 Hz, 1H), 1.60 (s, 3H), 1.60 (m, 2H), 1.59 (s, 3H), 1.58 (s, 3H), 1.50 (s, 3H), 1.46 (d, J = 9.4 Hz, 1H), 0.89 (s, 9H), 0.04 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 199.07, 198.46, 151.03, 149.36, 138.27, 138.19, 137.41, 135.57, 134.92, 124.41, 123.99, 119.84, 63.13, 60.50, 60.26, 59.55, 56.29, 54.67, 53.35, 43.70, 40.15, 39.91, 36.27, 36.01, 31.42, 26.88, 26.74, 26.19 (3C), 23.60, 18.57, 16.61, 16.23, 16.19, -5.03 (2C); ESI-MS (*m/z*): 611.5 $[M+H]^+$, 633.4 $[M+Na]^+$.

*Synthesis of **S43***

S43 was prepared from **S39** (26 mg, 0.037 mmol) according to the same procedure described for **S42**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 10% EtOAc/*n*-hexane) to provide **S43** as a yellow oil (18 mg, 0.021 mmol, 56%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.67 (m, 4H), 7.44-7.34 (m, 6H), 6.06 (m, 2H), 5.12-5.05 (m, 5H), 3.90 (s, 3H), 3.88 (s, 3H), 3.64 (t, J = 6.5 Hz, 2H), 3.10 (br s, 1H), 3.01 (br s, 1H), 2.75 (dd, J = 7.4, 15.1 Hz, 1H), 2.43 (dd, J = 6.3, 15.1 Hz, 1H), 2.08-1.92 (m, 18H), 1.78 (d, J = 9.4 Hz, 1H), 1.65 (m, 2H), 1.59 (s, 9H), 1.58 (s, 3H), 1.56 (s, 3H), 1.50 (s, 3H), 1.46 (d, J = 9.5 Hz, 1H), 1.05 (s, 9H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 199.09, 198.47, 151.03, 149.35, 138.28, 138.19, 137.40, 135.78 (4C), 135.62, 135.26, 135.17, 134.82, 134.36 (2C), 129.69 (2C), 127.78 (4C), 124.58, 124.43, 124.37, 123.96, 119.83, 63.81, 60.50, 60.26, 59.55, 56.29, 54.67, 53.35, 43.69, 40.16, 39.93 (3C), 36.27, 36.00, 31.18, 27.08 (3C), 26.94 (2C), 26.91, 26.75, 23.60, 19.44, 16.61, 16.25 (3C), 16.16; ESI-MS (*m/z*): 859.6 $[M+H]^+$.

*Synthesis of **S44***

S44 was prepared from **S40** (186 mg, 0.23 mmol) according to the same procedure described for **S42**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 5-15% EtOAc/*n*-hexane) to provide **S44** as a yellow oil (128 mg, 0.134 mmol, 58%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 6.05 (m, 2H), 5.12-5.04 (m, 8H), 3.89 (s, 3H), 3.87 (s, 3H), 3.57 (t, J = 6.6 Hz, 2H), 3.09 (br s, 1H), 3.00 (br s, 1H), 2.74 (dd, J = 7.4, 15.1 Hz, 1H), 2.41 (dd, J = 6.3, 15.1 Hz, 1H), 2.09-1.94 (m, 30H), 1.77 (d, J = 9.4 Hz, 1H), 1.59 (s, 21H), 1.58 (m, 2H), 1.57 (s, 3H), 1.49 (s, 3H), 1.45 (d, J = 9.4 Hz, 1H), 0.88 (s, 9H), 0.03 (s, 6H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 199.02, 198.40, 150.99, 149.32, 138.23, 138.16, 137.37, 135.56, 135.20, 135.12, 135.11, 135.09, 135.05, 134.76, 124.51, 124.46, 124.44, 124.43, 124.41, 124.32, 123.94, 119.81, 63.09, 60.45, 60.21, 59.51, 56.25, 54.64, 53.33, 43.65, 40.13, 39.93 (4C), 39.91 (2C), 36.25, 35.98,

31.38, 26.90 (4C), 26.87 (2C), 26.71, 26.17 (3C), 23.57, 18.53, 16.57, 16.22 (6C), 16.16, -5.03 (2C); ESI-MS (*m/z*): 951.7 $[M+H]^+$, 973.7 $[M+Na]^+$.

Synthesis of ***S45***

To a solution of **S42** (143 mg, 0.23 mmol) in THF (3 mL), 1.0 M HCl (3 mL) was added and the mixture was stirred for 1 h at rt. The reaction was quenched with saturated aqueous $NaHCO_3$, extracted with EtOAc and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 40% EtOAc/*n*-hexane) to provide an orange oil. The orange compound was dissolved in toluene (6 mL) and the solution was heated under reflux for 1 h. The solvent was removed *in vacuo* to provide **S45** as an orange oil (77 mg, 0.18 mmol, 85%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.13 (t, J = 6.6 Hz, 1H), 5.05 (t, J = 6.8 Hz, 1H), 4.94 (t, J = 7.0 Hz, 1H), 3.99 (s, 3H), 3.98 (s, 3H), 3.62 (t, J = 6.3 Hz, 2H), 3.18 (d, J = 6.9 Hz, 2H), 2.09-1.93 (m, 10H), 2.01 (s, 3H), 1.74 (s, 3H), 1.66 (m, 2H), 1.60 (s, 3H), 1.57 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.68, 183.84, 144.28, 144.14, 141.59, 138.78, 137.45, 134.96, 134.53, 124.61, 123.90, 118.82, 62.69, 61.05 (2C), 39.57, 39.51, 35.88, 30.60, 26.42, 26.32, 25.21, 16.22, 15.87, 15.74, 11.84; ESI-MS (*m/z*); 431.3 $[M+H]^+$, 653.2 $[M+Na]^+$.

Synthesis of ***S46***

S43 (18 mg, 0.021 mmol) was dissolved in toluene (3 mL) and the solution was heated under reflux for 2 h. The solvent was removed *in vacuo*, and the residue was dissolved in THF (3 mL) and cooled to 0 ˚C. AcOH (10 μL) and TBAF (31 μL, 1.0 M solution in THF, 0.031 mmol) were added to the solution and stirred for 20 h at rt. The reaction mixture was cooled to 0 ˚C and quenched with saturated aqueous NH_4Cl. The mixture was extracted with Et_2O and dried over anhydrous $MgSO_4$. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15-30% EtOAc/*n*-hexane) to provide **S46** as an orange oil (7 mg, 0.012 mmol, 59%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.17-5.03 (m, 4H), 4.94 (t, J = 6.7 Hz, 1H), 3.99 (s, 3H), 3.98 (s, 3H), 3.63 (t, J = 6.4 Hz, 2H), 3.18 (d, J = 7.0 Hz, 2H), 2.10-1.93 (m, 18H), 2.01 (s, 3H), 1.74 (s, 3H), 1.65 (m, 2H), 1.61 (s, 3H), 1.59 (s, 6H), 1.58 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 185.00, 184.15, 144.61, 144.46, 141.91, 139.09, 137.85, 135.46, 135.18, 134.99, 134.80, 125.04, 124.61, 124.40, 124.08, 119.08, 63.05, 61.36 (2C), 39.93 (3C), 39.85, 36.22, 30.95, 26.89 (2C), 26.79, 26.73, 25.52, 16.56, 16.25, 16.23, 16.19, 16.07, 12.16; ESI-MS (*m/z*): 567.4 $[M+H]^+$.

Synthesis of ***S47***

S47 was prepared from **S44** (128 mg, 0.13 mmol) according to the same procedure described for **S46**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 30% EtOAc/*n*-hexane) to provide **S47** as an orange solid (95 mg, 0.123 mmol, 92%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 5.17-

5.04 (m, 7H), 4.94 (tq, J = 1.2, 7.0 Hz, 1H), 3.99 (s, 3H), 3.98 (s, 3H), 3.62 (t, J = 6.5 Hz, 2H), 3.18 (d, J = 7.0 Hz, 2H), 2.10-1.92 (m, 30H), 2.01 (s, 3H), 1.74 (s, 3H), 1.67 (m, 2H), 1.61 (s, 3H), 1.60 (s, 15H), 1.58 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.94, 184.08, 144.56, 144.41, 141.86, 139.04, 137.79, 135.41, 135.16, 135.10 (2C), 135.07, 134.93, 134.75, 124.98, 124.58, 124.46, 124.43 (2C), 124.34, 124.03, 119.04, 62.98, 61.30 (2C), 39.92 (3C), 39.90 (3C), 39.82, 36.18, 30.92, 26.89 (3C), 26.86 (2C), 26.77, 26.69, 25.48, 16.52, 16.20 (5C), 16.15, 16.04, 12.11; ESI-MS (*m/z*): 771.6 $[M+H]^+$, 793.5 $[M+Na]^+$.

*Synthesis of **OS-UQ6***

OS-UQ6 was prepared from **S45** (9 mg, 0.021 mmol) according to the same procedure described for **OS-UQ2** (see p. S14). The crude product was purified by silica gel column chromatography (Wako gel® C-200, 20% EtOAc/*n*-hexane) to provide **OS-UQ6** as an orange oil (11 mg, 0.015 mmol, 69%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.00 (s, 2H), 5.14 (m, 1H), 5.05 (m, 1H), 4.93 (tq, J = 1.2, 7.0 Hz, 1H), 4.27 (t, J = 6.8 Hz, 2H), 4.08 (s, 3H), 3.99 (s, 3H), 3.98 (s, 3H), 3.45 (s, 6H), 3.18 (d, J = 7.0 Hz, 2H), 2.12-2.01 (m, 6H), 2.01 (s, 3H), 1.99-1.93 (m, 4H), 1.86 (m, 2H), 1.73 (s, 3H), 1.62 (s, 3H), 1.57 (s, 3H), 1.56 (s, 12H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.90, 184.34, 165.28, 165.21, 144.60, 144.46, 141.89, 139.08, 137.80, 135.31, 135.07 (2C), 133.81, 125.89, 125.40, 124.18, 119.10, 117.12 (2C), 96.73 (2C), 79.51 (2C), 71.25 (2C), 65.27, 61.35 (2C), 61.22, 52.05 (2C), 39.89, 39.83, 36.05, 28.41 (4C), 27.06, 26.89, 26.71, 25.52, 16.56, 16.24, 16.10, 12.15; ESI-MS (*m/z*): 779.4 $[M+Na]^+$.

*Synthesis of **OS-UQ7***

OS-UQ7 was prepared from **S46** (7 mg, 0.012 mmol) according to the same procedure described for **OS-UQ2**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15% EtOAc/*n*-hexane) to provide **OS-UQ7** as an orange oil (7 mg, 0.008 mmol, 64%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.00 (s, 2H), 5.16 (t, J = 6.4 Hz, 1H), 5.13-5.03 (m, 3H), 4.93 (t, J = 6.5 Hz, 1H), 4.27 (t, J = 6.7 Hz, 2H), 4.08 (s, 3H), 3.99 (s, 3H), 3.98 (s, 3H), 3.18 (d, J = 7.0 Hz, 2H), 2.13-1.92 (m, 18H), 2.01 (s, 3H), 1.86 (m, 2H), 1.63 (s, 3H), 1.59 (s, 6H), 1.58 (s, 3H), 1.57 (s, 3H), 1.56 (s, 12H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.99, 184.13, 165.28, 165.21, 144.61, 144.46, 141.91, 139.09, 137.85, 135.47, 135.20, 135.07 (2C), 135.01, 133.76, 125.90, 125.49, 124.58, 124.37, 124.06, 119.08, 117.12 (2C), 96.73 (2C), 79.52 (2C), 71.26 (2C), 65.28, 61.36 (2C), 61.22, 52.05 (2C), 39.93 (3C), 39.85, 36.05, 28.41 (4C), 27.07, 26.92 (3C), 26.74, 25.52, 16.56, 16.26, 16.23 (2C), 16.11, 12.15; ESI-MS (*m/z*): 893.5 $[M+H]^+$.

*Synthesis of **OS-UQ8***

OS-UQ8 was prepared from **S47** (23 mg, 0.030 mmol) according to the same procedure described for **OS-UQ2**. The crude product was purified by silica gel column chromatography (Wako gel® C-200, 15%

EtOAc/*n*-hexane) to provide **OS-UQ8** as an orange oil (16 mg, 0.015 mmol, 49%): ^{1}H-NMR (400 MHz, $CDCl_3$): δ 8.00 (s, 2H), 5.18-5.04 (m, 7H), 4.94 (tq, J = 1.2, 7.0 Hz, 1H), 4.27 (t, J = 6.7 Hz, 2H), 4.08 (s, 3H), 3.99 (s, 3H), 3.98 (s, 3H), 3.45 (s, 6H), 3.18 (d, J = 7.0 Hz, 2H), 2.13-1.93 (m, 30H), 2.01 (s, 3H), 1.86 (m, 2H), 1.74 (s, 3H), 1.63 (s, 3H), 1.59 (s, 15H), 1.58 (s, 3H); ^{13}C-NMR (100 MHz, $CDCl_3$): δ 184.97, 184.12, 165.27, 165.20, 144.60, 144.45, 141.90, 139.07, 137.84, 135.46, 135.21, 135.15 (2C), 135.13, 135.07 (2C), 134.98, 133.75, 125.89, 125.49, 124.59, 124.46 (3C), 124.36, 124.06, 119.07, 117.11 (2C), 96.72 (2C), 79.52 (2C), 71.24 (2C), 65.27, 61.34 (2C), 61.21, 52.04 (2C), 39.96 (3C), 39.93 (3C), 39.85, 36.05, 28.40 (4C), 27.07, 26.94 (4C), 26.91 (2C), 26.74, 25.52, 16.56, 16.24 (6C), 16.10, 12.15; ESI-MS (*m/z*): 1119.7 $[M+Na]^+$.

References (for the synthetic procedures)

1. Emmanuvel, L., Shukla, R. K., Sudalai, A., Gurunath, S., and Sivaram, S. (2006) *Tetrahedron Lett.* 47, 4793-4796.
2. Sonogashira, K. Tohda, Y., and Hagiwara, N. (1975) *Tetrahedron Lett.* 50, 4467.
3. Bal B. S., Childers, W. E., and Pinnick, H. W. (1981) *Tetrahedron* 37, 2091-2096.
4. Wang, J., Li, S., Yang,T., and Yang, J. (2014) *Eur. J. Med. Chem.* 86, 710-713.
5. Okuda, K., Murai, M., Aburaya, S., Aoki, W., and Miyoshi, H. (2016) *Biochemistry* 55, 470-481.
6. Boutagy, J. and Thomas, R. (1974) *Chem. Rev.* 74, 87-99.
7. Roe, S. J., Oldfield, M. F., Geach, N, and Baxter, A. (2013) *J. Labelled Compd. Radiopharm.* 56, 485-491.
8. Ito, T., Murai, M., Ninokura, S., Kitazumi, Y., Mezic, K. G., Cress, B. F., Koffas, M. A. G., Morgan, J. E., Barquera, B., and Miyoshi, H. (2017) *J. Biol. Chem.* 292, 7727-7742.
9. van der Klei, A., de Jong, R. L. P., Lugtenburg, J., and Tielens, A. G. M. (2002) *Eur. J. Org. Chem.* 2002. 3015-3023.