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## Supporting information

# Highly Efficient Synthesis of the Tricyclic Core of Taxol by Cascade Metathesis 

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## 1. General Experimental

Reactions involving air-sensitive agents and dry solvents were performed in glassware that had been dried in an oven $\left(150^{\circ} \mathrm{C}\right)$ or flame-dried prior to use. These reactions were carried out with the exclusion of air using an argon atmosphere. All microwave reactions were carried out using a Biotage Initiator system. M elting points were determined on a Stuart scientificM elting Point SM P1 apparatus and are uncorrected. NM R spectra were recorded on a Bruker DPX - 400 spectrometer ( 1 H NMR at 400 M Hz and 13 CNMR at 100 M Hz ) or a Bruker DPX-500 spectrometer ( 1 H NMR at 500 MHz and 13C NMR at 126 MHz ). Chemical shifts are reported in ppm. 1H NMR spectra were recorded with $\mathrm{CDC}_{13}$ as the solvent using residual $\mathrm{CHCl}_{3}$ (' $=7.26$ ) as internal standard, and for 13C NMR spectra the chemical shifts are reported relative to the central resonance of $\mathrm{CDCl}_{3}\left(^{\prime}=77.16\right)$. Signals in NMR spectra are described as singlet ( s ), doublet (d), triplet ( t ), quartet ( q ), quintet (quint), septet ( sept), multiplet (m), broad (br) or combination of these, which refers to the spin-spin coupling pattern observed. Spin-spin coupling constants reported are uncorrected. Two dimensional (COSY, HSQC, HM BC, NOESY) NMR spectroscopy was used where appropriate to assist the assignment of signals in the 1 H and 13C NM R spectra. IR spectra were obtained employing a Shimadzu FTIR-8400 instrument with a Golden Gate ${ }^{T M}$ attachment that uses a type Ila diamond as a single reflection element so that the IR spectrum of the compound (solid or liquid) could be detected directly (thin layer). High resolution mass spectra were recorded under FAB, ESI and CI conditions by the analytical services at the University of Glasgow. Flash column chromatography was performed using forced flow of the indicated solvent system on EM D Geduran Silica Gel 60 as solid support and HPLC graded solvents as eluant. Reactions were monitored by thin layer chromatography (TLC) on M erck silica gel 60 covered aluminum sheets. TLC plates were developed under UV-light and/or with an acidic ethanolic anisaldehyde solution or a $\mathrm{K} \mathrm{M} \mathrm{NO}_{4}$-solution. Liquid reagents were distilled prior to use where stated. All reagents were purchased from commercial suppliers and used without further purification unless otherwise stated.

## 2. Experimental Procedures and C haracterisation Data

## Ethyl 2,2-dimethylpent-4-ynoate



Formula: $\mathrm{C}_{9} \mathrm{H}_{14} \mathrm{O}_{2}$
M W: 154.2
Spect. Reference: J. Am. Chem. Soc. 2007, 129, 5838-5839
To a solution of DIPA ( $23 \mathrm{~mL}, 163 \mathrm{mmol}, 1.1$ equiv) in 400 mL of THF at $-78^{\circ} \mathrm{C}$ was added $\mathrm{nBuLi}(71 \mathrm{~mL}, 2.2 \mathrm{M}$ in hexane, $156 \mathrm{mmol}, 1.05$ equiv). The mixture was stirred at this temperature for 30 min and ethyl isobutyrate ( $20 \mathrm{~mL}, 149 \mathrm{mmol}$ ) in 300 mL of THF was added drop wise over 3 h and the reaction mixture was allowed to warm to $0^{\circ} \mathrm{C}$ for 45 min and then cooled down to $-78^{\circ} \mathrm{C}$. A solution of propargyl bromide ( $17.6 \mathrm{~mL}, 80 \%$ in toluene, 156 mmol ) in 100 mL of THF was added and the mixture was stirred at RT for 3 h . The reaction mixture was quenched with $\mathrm{NH}_{4} \mathrm{Cl}$ (sat. aq.) and the aqueous phase was extracted with DCM. The combined organic layers were washed with brine, dried over $\mathrm{MgSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was purified by flash chromatography on silica gel (petroleum ether/diethyl ether: $95 / 5$ ) to afford the title compound ( $20 \mathrm{~g}, 130 \mathrm{mmol}, 87 \%$ ) as a pale yellow oil.
${ }^{1} \mathbf{H}$ NMR $\left(400 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right)^{\prime} \mathrm{ppm}: 4.14(\mathrm{q}, \mathrm{J}=7.1 \mathrm{~Hz}, 2 \mathrm{H}), 2.43(\mathrm{~d}, \mathrm{~J}=2.6 \mathrm{~Hz}, 2 \mathrm{H}), 1.99(\mathrm{t}, \mathrm{J}$ $=2.6 \mathrm{~Hz}, 1 \mathrm{H}), 1.26(\mathrm{~s}, 6 \mathrm{H}), 1.24(\mathrm{~d}, \mathrm{~J}=7.1 \mathrm{~Hz}, 3 \mathrm{H})$.
${ }^{13} \mathbf{C} \mathbf{N M R}\left(100 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right){ }^{\prime} \mathrm{ppm}: 176.6,81.1,70.4,60.7,41.9,29.5,24.5,14.2$.
IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): $3296,2978,2934,2120,1727,1471,1386,1366,1317,1302,1255,1197,1130$, $1471,1386,1366,1317,1302,1255,1197,1132,1028$.

## 2,2-dimethylpent-4-ynoic acid (6)



Formula: $\mathrm{C}_{7} \mathrm{H}_{10} \mathrm{O}_{2}$
M W: 126.2
Spect. Reference: J. Am. Chem. Soc. 1983, 105, 5368-5372
To a solution of propargylated ethyl ester ( $20 \mathrm{~g}, 130 \mathrm{mmol}$ ) in 250 mL of MeOH and 100 mL of water was added KOH ( $11.7 \mathrm{~g}, 208 \mathrm{mmol}, 1.60$ equiv). The reaction mixture was stirred overnight at RT . A 2 N aqueous HCl solution was added to adjust the pH to 1 and the aqueous phase was extracted with DCM . The combined organic extracts were washed with a 2 N aqueous HCl solution, dried over $\mathrm{Na}_{2} \mathrm{SO}_{4}$, filtered and concentrated in vacuo to afford the title compound (6) $(15.3 \mathrm{~g}, 121 \mathrm{mmol}, 93 \%)$ as a pale yellow oil which can be used in the next step without further purification.
${ }^{1} \mathbf{H} \operatorname{NMR}\left(400 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right)^{\prime} \mathrm{ppm}: 2.47(\mathrm{~d}, \mathrm{~J}=2.7 \mathrm{~Hz}, 2 \mathrm{H}), 2.03(\mathrm{t}, \mathrm{J}=2.7 \mathrm{~Hz}, 1 \mathrm{H}), 1.32(\mathrm{~s}$, 6 H ).
${ }^{13} \mathrm{C}$ NMR ( $100 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) ' ppm: 183.2, 80.7, 70.7, 41.9, 29.3, 24.3.
IR ( $112 \mathrm{~cm}^{-1}$ ): 3515, 3297, 2977, 2936, 2120, 1699, 1474, 1410, 1367, 1316, 1283, 1227, 1160.
HRMS (EI) Calcd. for [ $\mathrm{C}_{7} \mathrm{H}_{10} \mathrm{O}_{2}$ ]: 126.0681, found: 126.0684.

## 2,2-Dimethylpent-3-ynoic acid (7)



Formula: $\mathrm{C}_{7} \mathrm{H}_{10} \mathrm{O}_{2}$
MW: 126.2
To a solution of acid (6) ( $17 \mathrm{~g}, 134 \mathrm{mmol}$ ) in DM SO ( 200 mL ) was added potassium tertbutoxide ( $32.9 \mathrm{~g}, 269 \mathrm{mmol}, 2.0$ equiv), and the mixture was stirred at $75^{\circ} \mathrm{C}$ for 10 min . A 1 N
aqueous HCl solution was then added to adjust to pH 1 , and the aqueous phase was extracted with $\mathrm{Et}_{2} \mathrm{O}$. The combined organic extracts were washed with 1 N aqueous HCl , dried over anhydrous $\mathrm{M} \mathrm{SSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/petroleum ether: $5 / 5$ ) to afford the title acid (7) ( $15.9 \mathrm{~g}, 94 \%$ ) as a pale yellow oil.

## 

${ }^{13} \mathrm{C}$ NM R ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) ' ppm: 180.6, 80.7, 78.1, 38.2, 27.2, 3.6.
IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3532, 2984, 2923, 1707, 1470, 1411, 1267, 1234, 1172, 1057.
HRMS (EI) Calcd. for [ $\mathrm{C}_{7} \mathrm{H}_{10} \mathrm{O}_{2}$ ]: 126.0681, found: 126.0685 .

## 2,2-Dimethylpent-3-ynal (7a)



Formula: $\mathrm{C}_{7} \mathrm{H}_{10} \mathrm{O}$
MW: 110.2
To a suspension of lithium aluminum hydride ( $0.75 \mathrm{~g}, 19.8 \mathrm{mmol}, 1.0$ equiv) in $\mathrm{Et}_{2} \mathrm{O}(90$ mL ) at $0^{\circ} \mathrm{C}$ was added dropwise a solution of ( 7 ) ( $2.5 \mathrm{~g}, 19.8 \mathrm{mmol}, 1.0$ equiv) in $\mathrm{Et}_{2} \mathrm{O}(10 \mathrm{~mL})$. The mixture was stirred at this temperature for 30 min . Excess of lithium aluminum hydride was then quenched with careful addition of ice. A 1 N aqueous HCl solution was then added to dissolve lithium salts. The aqueous phase was then extracted with $\mathrm{Et}_{2} \mathrm{O}$. The combined organic extracts were washed with 1 N aqueous HCl , dried over anhydrous $\mathrm{MgSO}_{4}$, filtered and concentrated in vacuo to give a pale yellow oil that was directly used without further purification. To a solution of oxalyl chloride ( $2.0 \mathrm{~mL}, 24 \mathrm{mmol}, 1.2$ equiv) in $\mathrm{CH}_{2} \mathrm{Cl}_{2}(40 \mathrm{~mL}$ ) at $-50^{\circ} \mathrm{C}$ was added dropwise DM SO ( $3.3 \mathrm{~mL}, 46 \mathrm{mmol}, 2.3$ equiv). The mixture was stirred at this temperature for 10 min , and a solution of the previous alcohol ( 19.8 mmol ) in $\mathrm{CH}_{2} \mathrm{Cl}_{2}(20 \mathrm{~mL})$ was then added. The mixture was stirred for 30 min , and triethylamine ( $17 \mathrm{~mL}, 120 \mathrm{mmol}, 6.0$ equiv) was added. The temperature was allowed to warm to $0^{\circ} \mathrm{C}$, and the mixture was stirred for 30 min . The reaction was quenched with saturated aqueous $\mathrm{NH}_{4} \mathrm{Cl}$. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{SSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by
flash chromatography on silica gel (dichloromethane/pentane: 20/80) to afford the title aldehyde (7a) ( $1.7 \mathrm{~g}, 76 \%$ ) as a colorless oil.
${ }^{1} \mathbf{H}$ NMR ( $400 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}$ ) $\delta$ ppm: $9.45(\mathrm{~s}, 1 \mathrm{H}), 1.84(\mathrm{~s}, 3 \mathrm{H}), 1.29(\mathrm{~s}, 6 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR ( $100 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) ${ }^{\prime}$ ppm: 199.0, 80.9, 79.6, 42.7, 23.2, 3.7.
IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 2983, 2924, 2872, 2816, 2715, 1737, 1466, 1391, 1364, 1264, 1246, 1056.
HRMS (EI) Calcd. for $\mathrm{C}_{7} \mathrm{H}_{10} \mathrm{O}: 110.0732$, found: 110.0736 .

## 2,3-Dimethylpent-4-en-2-ol (7b)



Formula: $\mathrm{C}_{7} \mathrm{H}_{14} \mathrm{O}$
MW: 114.2
Spect. Reference: J. Am. Chem. Soc. 1998, 120, 6609-6610
To a solution of crotyl chloride ( $30 \mathrm{~mL}, 70 \%, 190 \mathrm{mmol}$ ) in acetone ( 1 L ) and aqueous saturated $\mathrm{NH}_{4} \mathrm{Cl}(100 \mathrm{~mL})$ was added activated zinc dust ( 25 g , $380 \mathrm{mmol}, 2.0$ equiv). The resulting mixture was stirred at it for one week. A 1 N aqueous HCl solution was then added to dissolve zinc salts, and acetone was removed in vacuo. The aqueous phase was extracted with $\mathrm{Et}_{2} \mathrm{O}$. The combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{gSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/petroleum ether: 20/80) to afford ( 7 b ) ( $18 \mathrm{~g}, 83 \%$ ) as a colorless oil.
${ }^{1} \mathbf{H} \operatorname{NMR}\left(400 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.80(\mathrm{~m}, 1 \mathrm{H}), 5.10(\mathrm{~m}, 1 \mathrm{H}), 5.07(\mathrm{~d}, \mathrm{~J}=0.6 \mathrm{~Hz}, 1 \mathrm{H}), 2.20$ (dd, J = 13.9, 6.9 Hz, 1H), 1.68 (bs, 1H), $1.18(\mathrm{~s}, 3 \mathrm{H}), 1.15(\mathrm{~s}, 3 \mathrm{H}), 1.03(\mathrm{~d}, \mathrm{~J}=6.9 \mathrm{~Hz}, 3 \mathrm{H})$.
${ }^{13} \mathrm{C}$ NMR $\left(126 \mathrm{MHz}, \mathrm{CDCl}_{3}\right){ }^{\prime} \mathrm{ppm}: 140.6,116.3,72.3,49.4,27.2,26.6,15.2$.
IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3620, 3580, 3490, 3079, 2976, 2937, 2880, 1836, 1636, 1460, 1419, 1371, 1339, 1217, 1173, 1118, 1040, 1001, 943, 915.

MS (CI, DI, NH $)_{3}$ : $97,115\left(M+\mathrm{H}^{+}\right), 133,\left(\mathrm{M}+\mathrm{NH}_{4}{ }^{+}\right)$.

## 6,6-Dimethylnon-2-en-7-yn-5-ol (7c)



Formula: $\mathrm{C}_{11} \mathrm{H}_{18} \mathrm{O}$
M W : 166.3
To a solution of aldehyde (7a) ( $3.5 \mathrm{~g}, 31.5 \mathrm{mmol}$ ) and alcohol (7b) ( $5.4 \mathrm{~g}, 47.3 \mathrm{mmol}, 1.5$ equiv) in $\mathrm{CH}_{2} \mathrm{Cl}_{2}(170 \mathrm{~mL})$ was added $4 \AA$ molecular sieves ( 1.0 g ) and tin trifluoromethanesulfonate ( $0.6 \mathrm{~g}, 1.6 \mathrm{mmol}, 5 \mathrm{~mol} \%$ ). The mixture was stirred overnight at rt. A 1 N aqueous HCl solution was then added and the aqueous phase was extracted with $\mathrm{CH}_{2} \mathrm{Cl}_{2}$. The combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{gSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/petroleum ether: $2 / 98$ ) to afford (7c) ( $4.0 \mathrm{~g}, 76 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) as a colorless oil.

## E Isomer

${ }^{1} \mathbf{H}$ NMR (400M Hz, CDCl ${ }_{3}$ ) $\delta$ ppm: 5.47-5.67 (m, 2H), $3.28(\mathrm{~d}, \mathrm{~J}=10.6 \mathrm{~Hz}, 1 \mathrm{H}), 2.40(\mathrm{~m}, 1 \mathrm{H})$, $2.05(\mathrm{~m}, 1 \mathrm{H}), 1.85(\mathrm{bs}, 1 \mathrm{H}), 1.80(\mathrm{~s}, 3 \mathrm{H}), 1.69(\mathrm{~d}, \mathrm{~J}=5.0 \mathrm{~Hz}, 3 \mathrm{H}), 1.19(\mathrm{~s}, 3 \mathrm{H}), 1.16(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13} \mathbf{C} \mathbf{N M R}\left(100 \mathrm{MHz}, \mathrm{CDCl}_{3}\right){ }^{\prime} \mathrm{ppm}: 128.5,128.2,84.1,78.1,77.5,36.9,35.8,25.7,25.6,18.1$, 3.6.

IR (½ $\mathrm{cm}^{-1}$ ): 3563, 2970, 2923, 1711, 1456, 1391, 1364, 1190, 1062, 1013, 972.
HRMS (EI) Calcd. for [ $\mathrm{C}_{11} \mathrm{H}_{18} \mathrm{O}$ ]: 166.1358, found: 166.1358.

## Z Isomer

${ }^{1} \mathbf{H}$ NM R $\left(400 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.47-5.67(\mathrm{~m}, 2 \mathrm{H}), 3.3(\mathrm{~m}, 1 \mathrm{H}), 2.40(\mathrm{~m}, 1 \mathrm{H}), 2.21(\mathrm{~m}, 1 \mathrm{H})$, $1.85(\mathrm{bs}, 1 \mathrm{H}), 1.81(\mathrm{~s}, 3 \mathrm{H}), 1.65(\mathrm{~d}, \mathrm{~J}=6.5 \mathrm{~Hz}, 3 \mathrm{H}), 1.22(\mathrm{~s}, 3 \mathrm{H}), 1.18(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13} \mathbf{C} \mathbf{N M R}\left(100 \mathrm{MHz}, \mathrm{CDCl}_{3}\right){ }^{\prime} \mathrm{ppm}: 127.5,126.6,84.1,77.7,77.5,37.1,30.0,25.7,25.6,13.0$, 3.6.

## 6,6-DimethyInon-2-en-7-yn-5-one (8)



Formula: $\mathrm{C}_{11} \mathrm{H}_{16} \mathrm{O}$
MW: 164.2
To a solution of alcohol (7c) ( $0.42 \mathrm{~g}, 2.5 \mathrm{mmol}, \mathrm{E} / \mathrm{Z}=3: 1$ ) in THF ( 10 mL ) was added a solution of IBX ( $2.1 \mathrm{~g}, 7.5 \mathrm{mmol}, 3.0$ equiv) in DMSO ( 10 mL ). The mixture was stirred overnight. W ater was then added, and the mixture was stirred for 2 h to form a white precipitate that was filtered off on Celite. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{gSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/petroleum ether: $2 / 98$ ) to afford the title ketone (8) ( $0.38 \mathrm{~g}, 93 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) as a colorless oil.

## E Isomer

${ }^{1} \mathbf{H}$ NMR $\left(400 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.50-5.71(\mathrm{~m}, 2 \mathrm{H}), 3.48(\mathrm{~d}, \mathrm{~J}=5.3 \mathrm{~Hz}, 2 \mathrm{H}), 1.84(\mathrm{~s}, 3 \mathrm{H})$, $1.71(\mathrm{~d}, \mathrm{~J}=4.6 \mathrm{~Hz}, 3 \mathrm{H}), 1.32(\mathrm{~s}, 6 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR(100 M Hz, CDCl $)_{3}$ ' ppm: 209.4, 129.0, 123.9, 82.3, 79.1, 43.6, 41.6, 26.4, 18.1, 3.7.
IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 2982, 2923, 2857, 1715, 1455, 1381, 1363, 1252, 1113, 1079, 1038, 968.
HRMS (EI) Calcd. for [ $\mathrm{C}_{11} \mathrm{H}_{16} \mathrm{O}$ ]: 164.1201, found: 164.1199

## Z Isomer

${ }^{1} \mathbf{H} \mathbf{N M R}\left(400 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.50-5.71(\mathrm{~m}, 2 \mathrm{H}), 3.56(\mathrm{~d}, \mathrm{~J}=7.3 \mathrm{~Hz}, 2 \mathrm{H}), 1.85(\mathrm{~s}, 3 \mathrm{H})$, $1.65(\mathrm{~d}, \mathrm{~J}=6.5 \mathrm{~Hz}, 3 \mathrm{H}), 1.34(\mathrm{~s}, 6 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR ( $100 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}$ ) ' ppm: 208.9, 127.1, 122.8, 82.3, 79.2, 43.8, 36.2, 26.5, 13.2, 3.7.

## 2-(2-M ethylpent-3-yn-2-yl)-2-(trimethylsilyloxy)hex-4-enenitrile (8a)



Formula: $\mathrm{C}_{15} \mathrm{H}_{25} \mathrm{NOSi}$
M W: 263.5
To a solution of ketone (8) ( $1.0 \mathrm{~g}, 6.1 \mathrm{mmol}, \mathrm{E} / \mathrm{Z}=3: 1$ ) in $\mathrm{CH}_{2} \mathrm{Cl}_{2}(30 \mathrm{~mL})$ was added zinc iodide ( $0.2 \mathrm{~g}, 0.6 \mathrm{mmol}, 0.1$ equiv) and trimethylsilylcyanide ( $1.5 \mathrm{~mL}, 12.2 \mathrm{mmol}, 2.0$ equiv). The mixture was stirred at reflux for 2 h , and the solvent was removed in vacuo to give a yellow oil that was purified by flash chromatography on silica gel (diethylether/pentane: $1 / 99$ ) to afford the title compound (8a) ( $1.5 \mathrm{~g}, 93 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) as a colorless oil.

## E Isomer

${ }^{1} \mathbf{H}$ NMR (400M Hz, CDCl ${ }_{3}$ ) $\delta$ ppm: 5.53-5.67 (m, 2H), $2.67(\mathrm{dd}, \mathrm{J}=13.6,6.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.44(\mathrm{dd}$, $\mathrm{J}=13.5,6.9 \mathrm{~Hz}, 1 \mathrm{H}), 1.81(\mathrm{~s}, 3 \mathrm{H}), 1.74(\mathrm{~d}, \mathrm{~J}=5.1 \mathrm{~Hz}, 3 \mathrm{H}), 1.34(\mathrm{~s}, 3 \mathrm{H}), 1.23(\mathrm{~s}, 3 \mathrm{H}), 0.22(\mathrm{~s}$, 9 H ).
${ }^{13}$ C NMR ( $100 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) ${ }^{\prime}$ ppm: 130.6, 125.6, 120.2, 82.5, 79.7, 79.4, 40.7, 40.7, 26.1, 23.8, 18.2, 3.8, 1.8.

IR (1⁄2 $\left.\mathrm{cm}^{-1}\right)$ : 2982, 2963, 2921, 2243, 1702, 1450, 1381, 1363, 1253, 1139, 1117, 1052, 971.
HRMS (EI) Calcd. for [C $\left.{ }_{15} \mathrm{H}_{25} \mathrm{NOSi}\right]$ : 263.1705, found: 263.1701.

## Z Isomer

${ }^{1} \mathbf{H}$ NM R (400M Hz, CDCl ${ }_{3}$ ) $\delta$ ppm: $5.75(\mathrm{~m}, 1 \mathrm{H}), 5.53-5.67(\mathrm{~m}, 1 \mathrm{H}), 2.80(\mathrm{dd}, \mathrm{J}=14.5,7.1 \mathrm{~Hz}$, 1 H ), 2.58 ( $\mathrm{dd}, \mathrm{J}=14.6,7.8 \mathrm{~Hz}, 1 \mathrm{H}$ ), $1.82(\mathrm{~s}, 3 \mathrm{H}), 1.68(\mathrm{~d}, \mathrm{~J}=6.7,3 \mathrm{H}), 1.36(\mathrm{~s}, 3 \mathrm{H}), 1.26(\mathrm{~s}$, $3 \mathrm{H}), 0.23(\mathrm{~s}, 9 \mathrm{H})$.
${ }^{13}$ C NMR ( $100 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}$ ) ${ }^{\prime}$ ppm: 128.6, 124.6, 120.2, 82.6, 79.7, 79.5, 41.0, 35.1, 26.1, 23.8, 13.3, 3.7, 1.8.

## 2-(2-M ethylpent-3-yn-2-yl)-2-(trimethylsilyloxy)hex-4-enal ( $\pm 9$ )



Formula: $\mathrm{C}_{15} \mathrm{H}_{26} \mathrm{O}_{2} \mathrm{Si}$
MW: 266.5
To a solution of nitrile (8a) ( $0.38 \mathrm{~g}, 1.5 \mathrm{mmol}$ ) in hexane ( 10 mL ) at $-78^{\circ} \mathrm{C}$ was slowly added DIBALH ( $3.8 \mathrm{~mL}, 1 \mathrm{M}$ in hexane, $3.8 \mathrm{mmol}, 2.5$ equiv). The mixture was allowed to warm to $0^{\circ} \mathrm{C}$ and was stirred at this temperature for 20 min . The mixture was then cooled down to $78^{\circ} \mathrm{C}$, and AcOEt was added. A fter stirring for $10 \mathrm{~min}, \mathrm{SiO}_{2}(\sim 1 \mathrm{~g})$ was added. The mixture was then allowed to warm to rt overnight. A nhydrous $\mathrm{M} \mathrm{gSO}_{4}$ was added and the mixture was stirred for 1 h. The solids were filtered off, and the solvent was removed in vacuo to give an oil that was purified by flash chromatography on silica gel (diethylether/petroleum ether: $1 / 99$ ) to afford the title aldehyde ( $\mathbf{\pm 9}$ ) ( $0.26 \mathrm{~g}, 67 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) as a colorless oil.
${ }^{1} \mathbf{H}$ NMR (400M Hz, CDCl $\left.{ }_{3}\right) \delta \mathrm{ppm}: 9.83(\mathrm{~s}, 1 \mathrm{H}), 5.46(\mathrm{dt}, \mathrm{J}=13.0,6.3 \mathrm{~Hz}, 1 \mathrm{H}), 5.23(\mathrm{dt}, \mathrm{J}=$ $14.9,7.3 \mathrm{~Hz}, 1 \mathrm{H}), 2.90(\mathrm{dd}, \mathrm{J}=14.3,7.2 \mathrm{~Hz}, 1 \mathrm{H}), 2.39(\mathrm{dd}, \mathrm{J}=14.2,7.3 \mathrm{~Hz}, 1 \mathrm{H}), 1.79(\mathrm{~s}, 3 \mathrm{H})$, $1.62(\mathrm{~d}, \mathrm{~J}=6.3 \mathrm{~Hz}, 3 \mathrm{H}), 1.19(\mathrm{~s}, 3 \mathrm{H}), 1.06(\mathrm{~s}, 3 \mathrm{H}), 0.12(\mathrm{~s}, 9 \mathrm{H})$.
${ }^{13}$ C NMR ( $100 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) ${ }^{\prime} \mathrm{ppm}: 204.5,129.2,125.8,86.9,83.9,78.9,37.3,36.6,25.7,24.5$, 18.1, 3.7, 2.9.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 2977, 2958, 2856, 2722, 1738, 1450, 1379, 1361, 1249, 1168, 1121, 1049, 972.
HRMS (EI) Calcd. for [ $\mathrm{C}_{15} \mathrm{H}_{26} \mathrm{O}_{2} \mathrm{Si}$ ]: 266.1702, found: 266.1706.

## N -methoxy-N,2,2-trimethylpent-3-ynamide (10)



Formula: $\mathrm{C}_{9} \mathrm{H}_{15} \mathrm{NO}_{2}$
MW: 169.2

To a solution of acid (7) ( $4.25 \mathrm{~g}, 33.7 \mathrm{mmol}$ ) in dichloromethane ( 80 mL ) was added 1,1'-carbonyl diimidazole ( $6.55 \mathrm{~g}, 40.4 \mathrm{mmol}, 1.2$ equiv). The resulting mixture was stirred for 30 min , then $\mathrm{N}, 0$-dimethylhydroxylamine hydrochloride ( $3.94 \mathrm{~g}, 40.4 \mathrm{mmol}, 1.2$ equiv). The mixture was allowed to stir at rt for 16 h . The reaction mixture was then quenched with a solution of 1 N aqueous HCl and stirred vigorously for 10 min . The solution was separated and the aqueous layer was extracted with dichloromethane. The combined organic extracts were washed with a solution of 1 N aqueous HCl , washed with brine, dried over anhydrous $\mathrm{M} \mathrm{gSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (petroleum ether/diethyl ether: 95/5) to afford the title W einreb amide (10) (5.13 g, 90\%) as a colorless oil.
${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right){ }^{\prime} \mathrm{ppm}: 3.76(\mathrm{~s}, 3 \mathrm{H}), 3.23(\mathrm{~s}, 3 \mathrm{H}), 1.84(\mathrm{~s}, 3 \mathrm{H}), 1.44(\mathrm{~s}, 6 \mathrm{H})$.
${ }^{13} \mathrm{C}$ NMR $\left(126 \mathrm{MHz}, \mathrm{CDCl}_{3}\right)$ ' ppm: 174.0, 82.9, 76.5, $60.5,37.1,33.8,27.3,3.7$.
IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 2983, 2935, 2869, 2242, 1659, 1455, 1408, 1382, 1356, 1254, 1169, 1115, 1085, 1021, 999.

HRMS (CI, ISO) Calcd for [C $\left.{ }_{9} \mathrm{H}_{16} \mathrm{NO}_{2}\right]^{+}: \mathrm{m} / \mathrm{z}$ 170.1181, found 170.1186.

2,6,6-trimethyInon-2-en-7-yn-5-one (11)


Formula: $\mathrm{C}_{12} \mathrm{H}_{18} \mathrm{O}$
MW: 178.3
To a suspension of magnesium turnings ( $1.95 \mathrm{~g}, 80.9 \mathrm{mmol}, 10$ equiv) in THF ( 20 mL ) was added a catalytic amount of 1,2 -dibromoethane, followed by prenyl chloride ( $1.10 \mathrm{~mL}, 9.31$ mmol, 1.1 equiv) dropwise. The resulting suspension was stirred for 15 min . Then the freshly made Grignard reagent was added via cannula to a solution of Weinreb amide (10) (1.37 g, 8.1 $\mathrm{mmol})$ in THF $(20 \mathrm{~mL})$. The resulting mixture was allowed to stir at it for 1 h . The reaction was quenched with brine. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{SO}_{4}$, filtered and concentrated in
vacuo. The crude mixture was then purified by flash chromatography on silica gel (petroleum ether/diethyl ether: 99/1) to afford (11) ( $1.37 \mathrm{~g}, 7.7 \mathrm{mmol}, 95 \%$ ) as a colorless oil.
${ }^{1} \mathbf{H}$ NMR $\left(400 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.32(\mathrm{~m}, 1 \mathrm{H}), 3.48(\mathrm{~d}, \mathrm{~J}=5.6 \mathrm{~Hz}, 2 \mathrm{H}), 1.83(\mathrm{~s}, 3 \mathrm{H}), 1.74(\mathrm{~s}$, 3H), 1.63 ( $\mathrm{s}, 3 \mathrm{H}$ ), 1.32 ( $\mathrm{s}, 6 \mathrm{H}$ ).
${ }^{13}$ C NMR ( $100 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}$ ) ${ }^{\prime}$ ppm: 209.2, 134.9, 116.7, 82.3, 78.9, 43.6, 37.3, 26.4, 25.7, 18.1, 3.6.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 2981, 2923, 1716, 1450, 1380, 1264, 1113, 1080, 1040.
HRMS (CI, ISO) Calcd. for [ $\mathrm{C}_{12} \mathrm{H}_{19} \mathrm{O}$ ]: 179.1436, found: 179.1433.

## 5-M ethyl-2-(2-methylpent-3-yn-2-yl)-2-(trimethylsilyloxy)hex-4-enenitrile ( $\pm 11 \mathrm{a})$



Formula: $\mathrm{C}_{16} \mathrm{H}_{27} \mathrm{NOSi}$
MW: 277.48
To a solution of ketone ( $\mathbf{1 1}$ ) ( $1.25 \mathrm{~g}, 6.95 \mathrm{mmol})$ in 100 mL of $\mathrm{CH}_{2} \mathrm{Cl}_{2}$ was added $\mathrm{Znl}_{2}$ $(443 \mathrm{mg}, 1.39 \mathrm{mmol}, 0.2$ equiv) and TMSCN ( $2.8 \mathrm{~mL}, 21 \mathrm{mmol}, 3.0$ equiv). The reaction mixture was refluxed for 2 h and the solvent was removed in vacuo. A trap of aqueous $\mathrm{NaOCl} / \mathrm{NaOH}$ was set up to quench the excess of TMSCN. The crude mixture was purified by flash chromatography (petroleum ether/Et $\mathrm{t}_{2} \mathrm{O}$ : 99/1) to afford the title compound ( $\pm 11 \mathrm{a}$ ) ( 1.83 g , $6.59 \mathrm{mmol}, 95 \%$ ) as a colorless oil.
${ }^{1} \mathbf{H}$ NMR (400M Hz, CDCl $\left.{ }_{3}\right) \delta$ ppm: 5.34 (ddq, J $\left.=8.1,6.9,1.2 \mathrm{~Hz}, 1 \mathrm{H}\right), 2.73(\mathrm{ddt}, \mathrm{J}=14.5,6.9$, $0.8 \mathrm{~Hz}, 1 \mathrm{H}), 2.52(\mathrm{dd}, \mathrm{J}=14.5,8.1 \mathrm{~Hz}, 1 \mathrm{H}), 1.82(\mathrm{~s}, 3 \mathrm{H}), 1.79(\mathrm{~d}, \mathrm{~J}=1.2 \mathrm{~Hz}, 3 \mathrm{H}), 1.67(\mathrm{~s}, 3 \mathrm{H})$, $1.35(\mathrm{~s}, 3 \mathrm{H}), 1.25(\mathrm{~s}, 3 \mathrm{H}), 0.22(\mathrm{~s}, 9 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) ${ }^{\prime}$ ppm: 136.2, 120.2, 118.7, 82.5, 79.5, 79.2, 40.7, 36.0, 26.0, 26.0, 23.5, 18.1, 3.6, 1.5 .

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 2978, 2922, 2876, 2240, 1674, 1447, 1382, 1363, 1252, 1126, 1112, 1070.

HRMS (EI) Calcd for [ $\mathrm{C}_{16} \mathrm{H}_{27} \mathrm{NOSi}^{+}$: $\mathrm{m} / \mathrm{z} 277.1862$, found 277.1863.

## 5-M ethyl-2-(2-methylpent-3-yn-2-yl)-2-(trimethylsilyloxy)hex-4-enal ( $\pm 12$ )



Formula: $\mathrm{C}_{16} \mathrm{H}_{28} \mathrm{O}_{2} \mathrm{Si}$
M W: 280.48
To a solution of nitrile ( $\mathbf{\pm 1 1 \mathrm { a } )}(0.50 \mathrm{~g}, 1.8 \mathrm{mmol})$ in freshly distilled hexane ( 50 mL ) was added DIBALH ( $3.1 \mathrm{~mL}, 1 \mathrm{M}$ in hexane, $3.1 \mathrm{mmol}, 1.7$ equiv). The reaction mixture was allowed to warm to $0^{\circ} \mathrm{C}$ and was stirred at this temperature for 20 min . The mixture was then cooled down to $-78^{\circ} \mathrm{C}$, and EtOA c was added. A fter stirring for $10 \mathrm{~min}, \mathrm{SiO}_{2}(1.5 \mathrm{~g})$ was added. The mixture was then allowed to warm to room temperature overnight. Saturated aqueous $\mathrm{NH}_{4} \mathrm{Cl}$ was added, the aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{gSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was purified by flash chromatography ( $n$ Pentane $/ \mathrm{CH}_{2} \mathrm{Cl}_{2}$ : 9/1) to afford the title aldehyde ( $\mathbf{\pm 1 2 )}$ ( $0.40 \mathrm{~g}, 1.6 \mathrm{mmol}, 87 \%)$ as a colorless oil.
${ }^{1} \mathbf{H} \mathbf{N M} \mathbf{R}\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 9.83(\mathrm{~s}, 1 \mathrm{H}), 5.01(\mathrm{ddq}, \mathrm{J}=7.8,7.4,1.2 \mathrm{~Hz}, 1 \mathrm{H}), 2.93$ (ddq, $J=14.7,7.4,0.8 \mathrm{~Hz}, 1 \mathrm{H}), 2.46(\mathrm{dd}, \mathrm{J}=14.7,7.8 \mathrm{~Hz}, 1 \mathrm{H}), 1.82(\mathrm{~s}, 3 \mathrm{H}), 1.69(\mathrm{~d}, \mathrm{~J}=1.2 \mathrm{~Hz}, 3 \mathrm{H})$, $1.63(\mathrm{~s}, 3 \mathrm{H}), 1.24(\mathrm{~s}, 3 \mathrm{H}), 1.08(\mathrm{~s}, 3 \mathrm{H}), 0.13(\mathrm{~s}, 9 \mathrm{H})$.
${ }^{13}$ C NMR (126 M Hz, CDCl 3 ) $\delta$ ppm: 204.3, 134.6, 118.9, 87.3, 84.0, 78.8, 37.4, 32.1, 25.9, 25.7, 24.5, 17.8, 3.6, 2.7.

IR (1/2 $\left.\mathrm{cm}^{-1}\right): 2960,2921,2857,2725,2253,1734,1451,1380,1280,1249,1211,1152,1115$, 1049, 1021.

HRMS (ESI) Calcd for $\left[\mathrm{C}_{16} \mathrm{H}_{28} \mathrm{O}_{2} \mathrm{SiNa}\right]^{+}: \mathrm{m} / \mathrm{z} 303.1751$, found 303.1741.

## 1-((R*)-6-M ethyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-2-(2-methylpent-3-yn-2-yl)hex-4-

 ene-1,2-diol (18a) and (18b)

Formula: $\mathrm{C}_{41} \mathrm{H}_{50} \mathrm{O}_{3}$
M W : 590.8
To a solution of hydrazone ( $\mathbf{\pm 1 3}$ ) ( $1.0 \mathrm{~g}, 1.5 \mathrm{mmol}, 1.5$ equiv) in THF ( 8 mL ) at $-78^{\circ} \mathrm{C}$ was added dropwise tBuLi ( $2.4 \mathrm{~mL}, 1.4 \mathrm{M}$ in pentane, $3.3 \mathrm{mmol}, 3.3$ equiv). The solution turned dark red. The solution was stirred at this temperature for 30 min and warmed for a few min to room temperature and intense nitrogen bubbling appeared. The mixture was then cooled down to $-78^{\circ} \mathrm{C}$ and a solution of aldehyde ( $\mathbf{\pm 1 0}$ ) ( $0.26 \mathrm{~g}, 1.0 \mathrm{mmol}$ ) in THF ( 2 mL ) was then added. The resulting mixture was stirred at $-78^{\circ} \mathrm{C}$ for 5 h and became yellow. The reaction was quenched with saturated aqueous $\mathrm{NaHCO}_{3}$. The aqueous layer was extracted with Et 2 O , and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{SSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was dissolved in THF ( 10 mL ) and a 1 N aqueous solution of hydrochloric acid ( $1.5 \mathrm{~mL}, 1.5 \mathrm{mmol}, 1.5$ equiv) was then added. The resulting mixture was stirred at it overnight. The reaction was quenched with saturated aqueous $\mathrm{NaHCO}_{3}$. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{SSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/petroleum ether: 5/95) to afford (14a) (0.25 $\mathrm{g}, 43 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) and (14b) $(0.23 \mathrm{~g}, 40 \%, \mathrm{E} / \mathrm{Z}=3: 1)$, both as a white solids.

$\left.{ }^{1} \mathbf{H} \mathbf{N M} \mathbf{R}(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl})_{3}\right) \delta \mathrm{ppm}: 7.49(\mathrm{~m}, 6 \mathrm{H}), 7.32(\mathrm{t}, \mathrm{J}=7.7 \mathrm{~Hz}, 6 \mathrm{H}), 7.25(\mathrm{~m}, 3 \mathrm{H}), 6.16(\mathrm{t}$, $J=3.9 \mathrm{~Hz}, 1 \mathrm{H}), 5.65$ (ddd, J = 14.1, 7.0, 3.5 Hz, 1H), $5.37(\mathrm{~m}, 1 \mathrm{H}), 4.47(\mathrm{~d}, \mathrm{~J}=2.8 \mathrm{~Hz}, 1 \mathrm{H})$, $3.34(\mathrm{~s}, 1 \mathrm{H}), 3.10(\mathrm{~m}, 2 \mathrm{H}), 2.89(\mathrm{~d}, \mathrm{~J}=3.9 \mathrm{~Hz}, 1 \mathrm{H}), 2.46(\mathrm{~d}, \mathrm{~J}=7.0 \mathrm{~Hz}, 2 \mathrm{H}), 2.06$ (dd, J = 10.0, $5.8 \mathrm{~Hz}, 2 \mathrm{H}), 1.73(\mathrm{~d}, \mathrm{~J}=6.4 \mathrm{~Hz}, 3 \mathrm{H}), 1.71(\mathrm{~d}, \mathrm{~J}=6.4 \mathrm{~Hz}, 3 \mathrm{H}), 1.47-1.63(\mathrm{~m}, 8 \mathrm{H}), 1.32(\mathrm{~s}, 6 \mathrm{H})$, $1.04(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $\left.126 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}$ : 146.0, 144.6, 128.7, 128.3, 128.0, 127.8, 126.9, 126.2, $86.8,86.5,78.4,77.8,69.9,64.6,42.1,37.8,37.1,36.5,35.1,26.1,26.0,25.8,25.7,24.6,18.9$, 18.3, 3.7.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3610, 3506, 3062, 3034, 2935, 2872, 1598, 1555, 1491, 1449, 1384, 1358, 1223, $1182,1153,1086,1071,1034,972,909$.

HRMS (EI) Calcd. for $\left[\mathrm{C}_{41} \mathrm{H}_{50} \mathrm{O}_{3}\right]$ : 590.3760, found: 590.3753.
(1R*,2R*,E)-1-((R*)-6-methyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-2-(2-methylpent-3-yn-2-yl)hex-4-ene-1,2-diol (14b)

$\left.{ }^{1} \mathbf{H} \mathbf{N M R}(500 \mathrm{MHz}, \mathrm{CDCl})_{3}\right) \delta \mathrm{ppm}: 7.45(\mathrm{~d}, \mathrm{~J}=7.9 \mathrm{~Hz}, 5 \mathrm{H}), 7.27(\mathrm{~m}, 10 \mathrm{H}), 6.15(\mathrm{t}, \mathrm{J}=3.9 \mathrm{~Hz}$, $1 \mathrm{H}), 5.60(\mathrm{~m}, 1 \mathrm{H}), 5.30(\mathrm{~m}, 1 \mathrm{H}), 4.44(\mathrm{~s}, 1 \mathrm{H}), 3.24(\mathrm{~s}, 1 \mathrm{H}), 3.06(\mathrm{t}, \mathrm{J}=6.4 \mathrm{~Hz}, 2 \mathrm{H}), 2.79(\mathrm{~s}, 1 \mathrm{H})$,
$2.41(\mathrm{~d}, \mathrm{~J}=6.6 \mathrm{~Hz}, 2 \mathrm{H}), 2.05(\mathrm{dd}, \mathrm{J}=9.9,5.7 \mathrm{~Hz}, 2 \mathrm{H}), 1.65(\mathrm{~d}, \mathrm{~J}=7.5 \mathrm{~Hz}, 3 \mathrm{H}), 1.64(\mathrm{~s}, 3 \mathrm{H})$, $1.38-1.61(\mathrm{~m}, 8 \mathrm{H}), 1.28(\mathrm{~s}, 3 \mathrm{H}), 1.23(\mathrm{~s}, 3 \mathrm{H}), 1.13(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta \mathrm{ppm}: 147.0,144.5,128.8,128.7,128.5,127.8,126.9,126.5$, $86.6,86.4,78.4,77.8,70.4,64.4,42.1,37.8,36.7,35.6,35.0,26.2,26.1,25.9,25.0,24.5,18.8$, 18.3, 3.7.

IR (1⁄2 $\mathrm{cm}^{-1}$ ): 3610, 3512, 3062, 2933, 2857, 2736, 1955, 1899, 1819, 1598, 1491, 1449, 1384, 1358, 1222, 1182, 1153, 1073, 1034, 971.

HRMS (EI) Calcd. for [ $\mathrm{C}_{41} \mathrm{H}_{50} \mathrm{O}_{3}$ ]: 590.3760, found: 590.3752.

## 4-(But-2-enyl)-5-((S*)-6-methyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one



Formula: $\mathrm{C}_{42} \mathrm{H}_{48} \mathrm{O}_{4}$
MW: 616.8
To a solution of diol (14a) ( $0.45 \mathrm{~g}, 0.68 \mathrm{mmol}$ ) in DM F ( 15 mL ) was added sodium hydride ( $68 \mathrm{mg}, 60 \%$ in mineral oil, $1.7 \mathrm{mmol}, 2.5$ equiv) and carbonyl diimidazole ( $0.55 \mathrm{~g}, 3.4$ mmol, 5.0 equiv). The mixture was stirred at rt for 15 min . The reaction was quenched with saturated aqueous $\mathrm{NH}_{4} \mathrm{Cl}$. The aqueous layer was extracted with Et 2 O , and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{MgSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/ petroleum ether: $10 / 90$ ) to afford the title protected diol (14aa) ( $0.40 \mathrm{~g}, 95 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) as a white solid.

The same procedure repeated with (14b) ( $0.12 \mathrm{~g}, 0.20 \mathrm{mmol}$ ) afforded the desired title protected diol (14ba) ( $0.09 \mathrm{~g}, 73 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) as a white solid.

## (4R*,5R*)-4-((E)-but-2-enyl)-5-((S*)-6-methyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-4-(2-

 methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (14aa)
${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 7.48(\mathrm{~m}, 6 \mathrm{H}), 7.32(\mathrm{t}, \mathrm{J}=7.4 \mathrm{~Hz}, 6 \mathrm{H}), 7.25(\mathrm{t}, \mathrm{J}=7.3 \mathrm{~Hz}$, $3 \mathrm{H}), 5.82(\mathrm{t}, \mathrm{J}=3.9 \mathrm{~Hz}, 1 \mathrm{H}), 5.53(\mathrm{dtd}, \mathrm{J}=7.9,6.8,1.4 \mathrm{~Hz}, 1 \mathrm{H}), 5.41(\mathrm{~m}, 1 \mathrm{H}), 5.30(\mathrm{~s}, 1 \mathrm{H}), 3.11$ (dt, J = 8.8, 5.9 Hz, 1H), 3.03 (m, 1H), 2.80 (dd, J = 15.5, 6.5 Hz, 1H), 2.68 (dd, J = 15.6, 6.9 $\mathrm{Hz}, 1 \mathrm{H}), 2.12(\mathrm{dd}, \mathrm{J}=10.1,5.4 \mathrm{~Hz}, 2 \mathrm{H}), 1.84(\mathrm{~m}, 1 \mathrm{H}), 1.72(\mathrm{~s}, 3 \mathrm{H}), 1.68(\mathrm{dd}, \mathrm{J}=6.9,1.1 \mathrm{~Hz}$, 3 H ), 1.56-1.69 (m, 7H ), 1.36 ( $\mathrm{s}, 3 \mathrm{H}$ ), 1.30 ( $\mathrm{s}, 3 \mathrm{H}$ ), $1.10(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta \mathrm{ppm}: 155.4,144.5,139.0,132.7,128.7,127.8,127.6,126.9$, $126.1,89.4,86.4,83.1,80.0,79.7,64.1,41.8,36.9,36.8,35.4,35.2,26.2,25.9,24.9,24.7,24.3$, 18.6, 18.2, 3.8.

IR (1⁄2 $\mathrm{cm}^{-1}$ ): 3061, 3035, 2937, 2871, 1805, 1598, 1491, 1449, 1388, 1346, 1321, 1262, 1190, 1069, 1048, 970.

HRMS (EI) Calcd. for [ $\left.\mathrm{C}_{42} \mathrm{H}_{48} \mathrm{O}_{4}\right]$ : 616.3553, found: 616.3554.
(4R*,5R*)-4-((E)-but-2-enyl)-5-((R*)-6-methyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one(14ba)

${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 7.46(\mathrm{~d}, \mathrm{~J}=7.2 \mathrm{~Hz}, 6 \mathrm{H}), 7.31(\mathrm{t}, \mathrm{J}=7.4 \mathrm{~Hz}, 6 \mathrm{H}), 7.25(\mathrm{t}, \mathrm{J}$ $=7.2 \mathrm{~Hz}, 3 \mathrm{H}), 5.76(\mathrm{t}, \mathrm{J}=3.9 \mathrm{~Hz}, 1 \mathrm{H}), 5.45-5.54(\mathrm{~m}, 1 \mathrm{H}), 5.37(\mathrm{dd}, \mathrm{J}=13.9,7.6 \mathrm{~Hz}, 1 \mathrm{H}), 5.28$ $(\mathrm{s}, 1 \mathrm{H}), 3.06(\mathrm{~m}, 2 \mathrm{H}), 2.76(\mathrm{dd}, \mathrm{J}=15.6,6.6 \mathrm{~Hz}, 1 \mathrm{H}), 2.61(\mathrm{dd}, \mathrm{J}=15.6,6.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.13(\mathrm{dd}$, $\mathrm{J}=10.0,6.0 \mathrm{~Hz}, 2 \mathrm{H}), 1.36-1.74(\mathrm{~m}, 8 \mathrm{H}), 1.63(\mathrm{~d}, \mathrm{~J}=6.2 \mathrm{~Hz}, 3 \mathrm{H}), 1.55(\mathrm{~s}, 3 \mathrm{H}), 1.30(\mathrm{~s}, 6 \mathrm{H})$, 1.14 (s, 3H).
${ }^{13}$ C NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ ppm: 155.3, 144.3, 140.9, 131.3, 128.7, 128.7, 127.8, 127.0, $125.8,89.3,86.5,82.8,80.7,79.5,64.3,41.7,36.5,35.5,35.1,34.6,25.8,25.0,24.9,24.8,24.4$, 18.3, 18.2, 3.6.

IR (1⁄2 $\mathrm{cm}^{-1}$ ): 3062, 2938, 2873, 1806, 1598, 1491, 1449, 1388, 1379, 1321, 1263, 1190, 1070, 1047, 971, 908.

HRMS (EI) Calcd. for [ $\left.\mathrm{C}_{42} \mathrm{H}_{48} \mathrm{O}_{4}\right]$ : 616.3553 , found: 616.3546 .

## 4-(But-2-enyl)-5-((S*)-6-(3-hydroxypropyl)-6-methylcyclohex-1-enyl)-4-(2-methylpent-3-yn-2-yll-1,3-dioxolan-2-one



Formula: $\mathrm{C}_{23} \mathrm{H}_{34} \mathrm{O}_{4}$
MW: 374.5
To a solution of protected alcohol (14aa) ( $0.40 \mathrm{~g}, 0.65 \mathrm{mmol}$ ) in $\mathrm{MeOH}(20 \mathrm{~mL})$ was added A mberlyst $\mathrm{H}-15$ ( 0.2 g ). The mixture was stirred at rt for 2 days. The resin was filtered off and the solvents were removed in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/ petroleum ether: $20 / 80$ to $50 / 50$ ) to afford the primary alcohol (14ab) ( $0.22 \mathrm{~g}, 90 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) as a colorless viscous oil.

The same procedure repeated with the Taxol like protected alcohol (14ba) ( $90 \mathrm{mg}, 0.15$ mmol ) afforded the desired Taxol like alcohol the primary alcohol (14bb) ( $51 \mathrm{mg}, 91 \%, \mathrm{E} / \mathrm{Z}=$ 3:1) as a colorless viscous oil.


[^0](4R*,5R*)-4-((E)-but-2-enyl)-5-((R*)-6-(3-hydroxypropyl)-6-methylcyclohex-1-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (14bb)


[^1]$\mathrm{Hz}, 1 \mathrm{H}), 2.12(\mathrm{dd}, \mathrm{J}=10.2,6.1 \mathrm{~Hz}, 1 \mathrm{H}), 1.81(\mathrm{~s}, 3 \mathrm{H}), 1.66(\mathrm{dd}, \mathrm{J}=6.1,1.2 \mathrm{~Hz}, 3 \mathrm{H}), 1.38-1.61$ (m, 8H), 1.32 (s, 3H), $1.30(\mathrm{~s}, 3 \mathrm{H}), 1.13(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ ppm: 155.4, 140.9, 131.3, 128.0, 125.9, 89.5, 82.8, 81.2, 79.6, $63.6,41.9,36.5,35.6,35.0,34.9,27.2,25.8,25.0,24.9,18.4,18.2,3.7$.

IR (1⁄2 $\mathrm{cm}^{-1}$ ): 3638, 2937, 2874, 1806, 1462, 1388, 1379, 1321, 1255, 1189, 1111, $1047,971$.
HRMS (EI) Calcd. for [ $\mathrm{C}_{23} \mathrm{H}_{34} \mathrm{O}_{4}$ ]: 374.2457, found: 374.2457.

## 5-((S*)-6-Allyl-6-methylcyclohex-1-enyl)-4-(but-2-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (15a) and (15b)



Formula: $\mathrm{C}_{23} \mathrm{H}_{32} \mathrm{O}_{3}$
M W: 356.5
To a solution of primary alcohol (14ab) ( $75 \mathrm{mg}, 0.20 \mathrm{mmol}$ ) in THF ( 3 mL ) was added onitrophenylselenocyanate ( $110 \mathrm{mg}, 0.49 \mathrm{mmol}, 2.4$ equiv) and tri-n-butylphosphine ( $120 \mu \mathrm{~L}$, $0.49 \mathrm{mmol}, 2.4$ equiv). The mixture was stirred at rt for 20 min . The reaction was quenched with water. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{MgSO}_{4}$, filtered and concentrated in vacuo to give a brown oil that was used without further purification. A solution of ammonium molybdate ( 86 mg ) in water ( 6 mL ) and aqueous hydrogen peroxide ( 3 mL ) was then prepared. This solution ( 1.7 mL ) was added at $-10^{\circ} \mathrm{C}$ to a solution of the previous compound in THF ( 2 mL ). The mixture was stirred at this temperature for 20 min . The reaction was quenched with water. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{SSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/ petroleum ether: 5/95) to afford (15a) ( $60 \mathrm{mg}, 84 \%, \mathrm{E} / \mathrm{Z}=3: 1$ ) as a pale yellow viscous oil.

The same procedure repeated with Taxol like primary alcohol (14bb) ( $33 \mathrm{mg}, 88 \mu \mathrm{~mol}$ ) afforded the desired Taxol like triene (15b) ( $27 \mathrm{mg}, 86 \%, E / Z=3: 1$ ) as a pale yellow viscous oil.

## (4R*,5R*)-5-((S*)-6-allyl-6-methylcyclohex-1-enyl)-4-((E)-but-2-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (15a)


${ }^{1} \mathbf{H} \mathbf{N M} \mathbf{R}\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.79(\mathrm{~m}, 2 \mathrm{H}), 5.50(\mathrm{dtd}, \mathrm{J}=14.9,6.8,1.3 \mathrm{~Hz}, 1 \mathrm{H}), 5.37(\mathrm{~m}$, $1 \mathrm{H}), 5.27(\mathrm{~s}, 1 \mathrm{H}), 5.08(\mathrm{~m}, 2 \mathrm{H}), 2.76(\mathrm{dd}, \mathrm{J}=15.5,6.5 \mathrm{~Hz}, 1 \mathrm{H}), 2.66(\mathrm{dd}, \mathrm{J}=15.6,6.9 \mathrm{~Hz}, 1 \mathrm{H})$, 2.38 (dd, J = 14.2, 6.7 Hz, 1H), $2.15(\mathrm{dd}, \mathrm{J}=12.5,6.3 \mathrm{~Hz}, 1 \mathrm{H}), 2.10(\mathrm{~m}, 2 \mathrm{H}), 1.77(\mathrm{~s}, 3 \mathrm{H}), 1.65$ (dd, J = 6.3, 1.1 Hz, 1H ), 1.54-1.70 (m, 4H), 1.32 (s, 3H), $1.29(\mathrm{~s}, 3 \mathrm{H}), 1.08(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $\left.126 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta$ ppm: 155.4, 139.1, 134.2, 132.7, 127.7, 126.0, 118.1, 89.4, 83.1, 80.0, 79.7, 44.9, 41.7, 36.9, 35.7, 35.5, 25.8, 25.4, 24.9, 24.7, 18.3, 18.2, 3.7.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): $3075,2979,2936,2856,1805,1638,1516,1430,1389,1378,1323,1237,1190$, 1173, 1133, 1311, 1048, 971, 917.

HRMS (EI) Calcd. for [ $\mathrm{C}_{23} \mathrm{H}_{32} \mathrm{O}_{3}$ ]: 356.2352, found: 356.2352.
(4R* $\left.5 \mathrm{R}^{*}\right)-5-\left(\left(\mathrm{R}^{*}\right)-6-\right.$ allyl-6-methylcyclohex-1-enyl)-4-((E)-but-2-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (15b)

${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.77(\mathrm{~m}, 2 \mathrm{H}), 5.51(\mathrm{~m}, 1 \mathrm{H}), 5.42(\mathrm{~m}, 1 \mathrm{H}), 5.29(\mathrm{~s}, 1 \mathrm{H}), 5.07$ $(\mathrm{m}, 2 \mathrm{H}), 2.80(\mathrm{~m}, 1 \mathrm{H}), 2.67(\mathrm{dd}, \mathrm{J}=15.6,7.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.31(\mathrm{dd}, \mathrm{J}=15.6,6.7 \mathrm{~Hz}, 1 \mathrm{H}), 2.13(\mathrm{~m}$, 3H), 1.76 (s, 3H), 1.67 (dd, J = 6.2, $0.9 \mathrm{~Hz}, 1 \mathrm{H}), 1.61(\mathrm{~m}, 4 \mathrm{H}), 1.33(\mathrm{~s}, 3 \mathrm{H}), 1.30(\mathrm{~s}, 3 \mathrm{H}), 1.13(\mathrm{~s}$, 3 H ).
${ }^{13}$ C NMR ( $126 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}$ ) $\delta$ ppm: 155.3, 140.7, 134.4, 131.8, 128.0, 125.9, 118.0, 89.4, 83.1, $80.6,79.9,43.4,41.7,37.0,35.7,34.9,25.8,25.0,24.7,18.2,18.2,3.7$.

IR (1⁄2 $\mathrm{cm}^{-1}$ ): 3077, 2936, 2857, 1813, 1698, 1638, 1591, 1522, 1462, 1389, 1378, 1347, 1330, 1255, 1189, 1146, 1111, 1046, 997, 971, 917.

HRMS (EI) Calcd. for $\mathrm{C}_{23} \mathrm{H}_{32} \mathrm{O}_{3}$ : 356.2352, found: 356.2366 .

5-M ethyl-1-((S)-6-methyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-2-(2-methylpent-3-yn-2-yl)hex-4-ene-1,2-diol (16a) and (16b)


Formula: $\mathrm{C}_{42} \mathrm{H}_{52} \mathrm{O}_{3}$
M W: 604.9
To a solution of hydrazone (13) ( $2.02 \mathrm{~g}, 1.80 \mathrm{mmol}, 1.5$ equiv) in THF ( 15 mL ) at $-78^{\circ} \mathrm{C}$ was added dropwise tB uLi ( $4.6 \mathrm{~mL}, 1.4 \mathrm{M}$ in hexane, $6.4 \mathrm{mmol}, 3.3$ equiv). The solution turned black red. The solution was stirred at this temperature for 30 min and warmed for a few min to room temperature and intense nitrogen bubbling appeared. The mixture was then cooled down to $-78^{\circ} \mathrm{C}$ and a solution of aldehyde ( $\pm \mathbf{1 2}$ ) ( $\left.545 \mathrm{mg}, 1.94 \mathrm{mmol}\right)$ in THF $(5 \mathrm{~mL})$ was then added. The resulting mixture was stirred at $-78^{\circ} \mathrm{C}$ for 5 h and became yellow. The reaction was quenched with saturated aqueous $\mathrm{NaHCO}_{3}$. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{MgSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was dissolved in THF ( 10 mL ) and a 1 N aqueous solution of $\mathrm{HCl}(2.9 \mathrm{~mL}, 2.9 \mathrm{mmol}, 1.5$ equiv) was then added. The resulting mixture was stirred at room temperature overnight. The reaction was quenched with saturated aqueous $\mathrm{NaHCO}_{3}$. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with
brine, dried over anhydrous $\mathrm{M} \mathrm{gSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/Et $\mathrm{t}_{2} \mathrm{O}: 95 / 5$ ) to afford the title compound (16a) ( $440 \mathrm{mg}, 0.73 \mathrm{mmol}, 38 \%$ ) and the title compound (16b) ( $440 \mathrm{mg}, 0.73 \mathrm{mmol}, 38 \%$ ) as colorless highly viscous oils.

## (1R , 2R )-5-M ethyl-1-((S)-6-methyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-2-(2-methylpent-

 3-yn-2-yl)hex-4-ene-1,2-diol (16a)
${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 7.47(\mathrm{dd}, \mathrm{J}=8.3,1.1 \mathrm{~Hz}, 6 \mathrm{H}), 7.34-7.28(\mathrm{~m}, 6 \mathrm{H}), 7.26-7.21$ $(\mathrm{m}, 3 \mathrm{H}), 6.16(\mathrm{t}, \mathrm{J}=4.0 \mathrm{~Hz}, 1 \mathrm{H}), 5.43(\mathrm{ddq}, \mathrm{J}=8.2,6.8,1.6 \mathrm{~Hz}, 1 \mathrm{H}), 4.48(\mathrm{~d}, \mathrm{~J}=4.5 \mathrm{~Hz}, 1 \mathrm{H})$, $3.32(\mathrm{~s}, 1 \mathrm{H}), 3.15-3.02(\mathrm{~m}, 2 \mathrm{H}), 2.81(\mathrm{~d}, \mathrm{~J}=4.5 \mathrm{~Hz}, 1 \mathrm{H}), 2.42(\mathrm{~m}, 2 \mathrm{H}), 2.08-2.01(\mathrm{~m}, 2 \mathrm{H}), 1.74-$ $1.71(\mathrm{~m}, 1 \mathrm{H}), 1.73(\mathrm{~s}, 3 \mathrm{H}), 1.72(\mathrm{~s}, 3 \mathrm{H}), 1.69-1.48(\mathrm{~m}, 9 \mathrm{H}), 1.32-1.40(\mathrm{~m}, 1 \mathrm{H}), 1.30(\mathrm{~s}, 3 \mathrm{H}), 1.30$ (s, 3H), 1.03 (s, 3H).
${ }^{13}$ C NMR (126 M Hz, $\left.\mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 146.3,144.5,131.2,128.7,128.2,127.7,126.8,121.6$, $86.9,86.4,78.3,78.3,70.0,64.5,42.0,37.1,36.5,35.2,33.3,26.3,26.2,26.0,25.8,25.7,24.6$, 18.8, 18.0, 3.6.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3500, 3482, 3090, 3063, 3029, 2957, 2936, 2873, 2250, 1682, 1652, 1490, 1448, 1381, 1226, 1092, 1070, 1037, 996.

HRMS (CI, ISO) Calcd for $\left[\mathrm{C}_{42} \mathrm{H}_{53} \mathrm{O}_{3}\right]^{+}$: m/z 605.3995, found 605.3996.
$[ \pm]_{\mathrm{D}}^{25}:+11.4\left(\mathrm{C} 0.9, \mathrm{CH}_{2} \mathrm{Cl}_{2}\right)$.

${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 7.44(\mathrm{dd}, \mathrm{J}=8.3,1.1 \mathrm{~Hz}, 6 \mathrm{H}), 7.31-7.27(\mathrm{~m}, 6 \mathrm{H}), 7.25-7.21$ $(\mathrm{m}, 3 \mathrm{H}), 6.17(\mathrm{t}, \mathrm{J}=4.0 \mathrm{~Hz}, 1 \mathrm{H}), 5.38(\mathrm{ddq}, \mathrm{J}=8.3,7.0,1.4 \mathrm{~Hz}, 1 \mathrm{H}), 4.46(\mathrm{~d}, \mathrm{~J}=4.7 \mathrm{~Hz}, 1 \mathrm{H})$, $3.22(\mathrm{~s}, 1 \mathrm{H}), 3.08-3.03(\mathrm{~m}, 2 \mathrm{H}), 2.72(\mathrm{~d}, \mathrm{~J}=4.7 \mathrm{~Hz}, 1 \mathrm{H}), 2.41(\mathrm{dd}, \mathrm{J}=15.8,7.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.35$ (dd, J = 15.8, 7.0 Hz, 1H), 2.07-2.00 (m, 2H), 1.67 (d, J = 1.1 Hz, 3H), 1.64 (s, 3H ), 1.64-1.50 $(\mathrm{m}, 6 \mathrm{H}), 1.49(\mathrm{~s}, 3 \mathrm{H}), 1.44-1.37(\mathrm{~m}, 2 \mathrm{H}), 1.27(\mathrm{~s}, 3 \mathrm{H}), 1.26(\mathrm{~s}, 3 \mathrm{H}), 1.13(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR (126 MHz, CDCl 3 ) $\delta$ ppm: 147.4, 144.4, 131.2, 128.6, 127.7, 127.5, 126.8, 121.4, 86.7, 86.4, 78.3, 78.3, 70.5, 64.5, 42.0, 36.7, 35.6, 35.0, 33.5, 26.4, 26.3, 26.0, 25.9, 24.9, 24.5, 18.7, 18.0, 3.5.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3615, 3501, 3088, 3062, 3026, 2959, 2933, 2870, 2249, 1685, 1648, 1541, 1489, 1448, 1378, 1363, 1341, 1229, 1088, 1074, 1053, 992.

HRMS (EI) Calcd for $\left[\mathrm{C}_{42} \mathrm{H}_{52} \mathrm{O}_{3}\right]^{+}: \mathrm{m} / \mathrm{z}$ 604.3916, found 604.3919.
$[ \pm]_{\mathrm{D}}^{25}:+2.5\left(\mathrm{C} 0.5, \mathrm{CH}_{2} \mathrm{Cl}_{2}\right)$.

5-((S)-6-M ethyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-4-(3-methylbut-2-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one


To a solution of (16a) ( $300 \mathrm{mg}, 0.48 \mathrm{mmol}$ ) in DM F ( 15 mL ) was added sodium hydride ( $70 \mathrm{mg}, 60 \%$ in mineral oil, $1.8 \mathrm{mmol}, 2.5$ equiv) and carbonyl diimidazole ( $569 \mathrm{mg}, 3.51 \mathrm{mmol}$, 5.0 equiv). The mixture was stirred at room temperature for 30 min . The reaction was quenched with saturated aqueous $\mathrm{NH}_{4} \mathrm{Cl}$. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{gSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/ $/ \mathrm{Et}_{2} \mathrm{O}$ : $9 / 1$ ) to afford the title compound (16aa) ( $284 \mathrm{mg}, 0.45 \mathrm{mmol}, 93 \%$ ) as a colorless highly viscous oil.

The same procedure was repeated with (16b) ( $425 \mathrm{mg}, 0.70 \mathrm{mmol}$ ) to afford the title compound (16ba) ( $420 \mathrm{mg}, 0.66 \mathrm{mmol}, 95 \%$ ) as a colorless highly viscous oil.

## (4R , 5R )-5-((S)-6-M ethyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-4-(3-methylbut-2-enyl)-4-

 (2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (16aa)
${ }^{1} \mathbf{H} \mathbf{N M R}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 7.46(\mathrm{dd}, \mathrm{J}=8.3,1.1 \mathrm{~Hz}, 6 \mathrm{H}), 7.33-7.29(\mathrm{~m}, 6 \mathrm{H}), 7.26-7.21$ $(\mathrm{m}, 3 \mathrm{H}), 5.83(\mathrm{t}, \mathrm{J}=4.0 \mathrm{~Hz}, 1 \mathrm{H}), 5.34-5.28(\mathrm{~m}, 2 \mathrm{H}), 3.11-3.03(\mathrm{~m}, 2 \mathrm{H}), 2.74(\mathrm{dd}, \mathrm{J}=16.0,6.3$ $\mathrm{Hz}, 1 \mathrm{H}), 2.65(\mathrm{dd}, \mathrm{J}=16.0,7.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.10(\mathrm{dt}, \mathrm{J}=6.7,4.6 \mathrm{~Hz}, 2 \mathrm{H}), 1.88-1.79(\mathrm{~m}, 1 \mathrm{H}), 1.72$ $(\mathrm{s}, 3 \mathrm{H}), 1.71(\mathrm{~d}, \mathrm{~J}=1.0 \mathrm{~Hz}, 3 \mathrm{H}), 1.68-1.58(\mathrm{~m}, 8 \mathrm{H}), 1.41-1.34(\mathrm{~m}, 2 \mathrm{H}), 1.33(\mathrm{~s}, 3 \mathrm{H}), 1.29(\mathrm{~s}$, $3 \mathrm{H}), 1.11(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR (126 M Hz, $\left.\mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 155.4,144.5,139.2,132.5,132.1,128.7,127.7,126.8$, $119.3,89.9,86.4,83.3,80.0,79.6,64.1,41.8,36.9,36.7,35.3,31.1,26.4,25.9,25.8,24.9,24.7$, 24.3, 18.5, 18.0, 3.7.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3088, 3059, 3028, 2936, 2873, 2249, 1797, 1656, 1649, 1541, 1489, 1448, 1389, 1330, 1211, 1181, 1062, 1033.

HRMS (ESI) Calcd for $\left[\mathrm{C}_{43} \mathrm{H}_{50} \mathrm{O}_{4} \mathrm{Na}\right]^{+}: \mathrm{m} / \mathrm{z} 653.3601$, found 653.3575.
$[ \pm]_{\mathrm{D}}^{25}:-3.6\left(\mathrm{C} 0.65, \mathrm{CH}_{2} \mathrm{Cl}_{2}\right)$.

## (4S,5S)-5-((S)-6-M ethyl-6-(3-(trityloxy)propyl)cyclohex-1-enyl)-4-(3-methylbut-2-enyl)-4-

 (2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (16ba)
${ }^{1} \mathbf{H} \mathbf{N M R}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 7.43(\mathrm{dd}, \mathrm{J}=8.4,1.3 \mathrm{~Hz}, 6 \mathrm{H}), 7.32-7.27(\mathrm{~m}, 6 \mathrm{H}), 7.25-7.21$ $(\mathrm{m}, 3 \mathrm{H}), 5.76(\mathrm{t}, \mathrm{J}=4.0 \mathrm{~Hz}, 1 \mathrm{H}), 5.31-5.26(\mathrm{~m}, 2 \mathrm{H}), 3.11-3.02(\mathrm{~m}, 2 \mathrm{H}), 2.69(\mathrm{ddq}, \mathrm{J}=16.2,6.3$, $1.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.58(\mathrm{dd}, \mathrm{J}=16.2,7.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.16-2.06(\mathrm{~m}, 2 \mathrm{H}), 1.73-1.68(\mathrm{~m}, 1 \mathrm{H}), 1.66(\mathrm{~d}, \mathrm{~J}=$ $1.2 \mathrm{~Hz}, 3 \mathrm{H}), 1.63-1.58(\mathrm{~m}, 4 \mathrm{H}), 1.57(\mathrm{~s}, 3 \mathrm{H}), 1.51(\mathrm{~s}, 3 \mathrm{H}), 1.49-1.45(\mathrm{~m}, 2 \mathrm{H}), 1.43-1.38(\mathrm{~m}, 1 \mathrm{H})$, $1.29(\mathrm{~s}, 3 \mathrm{H}), 1.28(\mathrm{~s}, 3 \mathrm{H}), 1.13(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR (126 M Hz, $\mathrm{CDCl}_{3}$ ) $\delta$ ppm: 155.2, 144.4, 141.3, 132.4, 131.1, 128.7, 127.7, 126.9, $119.1,89.9,86.6,83.0,80.8,79.4,64.4,41.9,36.6,35.5,34.9,31.2,26.0,25.8,25.0,25.0,24.8$, 24.5, 18.3, 18.1, 3.5.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3089, 3063, 3026, 2940, 2873, 2254, 1790, 1652, 1597, 1541, 1489, 1448, 1382, 1333, 1211, 1185, 1066, 1037.

HRMS (ESI) Calcd for $\left[\mathrm{C}_{43} \mathrm{H}_{50} \mathrm{O}_{4} \mathrm{Na}\right]^{+}: \mathrm{m} / \mathrm{z} 653.3601$, found 653.3573.
$[ \pm]_{\mathrm{D}}^{25}:+3.7\left(\mathrm{C} 0.65, \mathrm{CH}_{2} \mathrm{Cl}_{2}\right)$.

5-((S)-6-(3-Hydroxypropyl)-6-methylcyclohex-1-enyl)-4-(3-methylbut-2-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one


Formula: $\mathrm{C}_{24} \mathrm{H}_{36} \mathrm{O}_{4}$
M W : 388.5
To a solution of protected diol (16aa) ( $391 \mathrm{mg}, 0.62 \mathrm{mmol}$ ) in $\mathrm{M} \mathrm{eOH}(20 \mathrm{~mL})$ was added A mberlyst H-15 ( 0.15 g ). The mixture was stirred at room temperature for 2 days. The resin was filtered off and the solvents were removed in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/ $\mathrm{Et}_{2} \mathrm{O}: 8 / 2$ to $5 / 5$ ) to afford the title primary alcohol (16ab) ( $214 \mathrm{mg}, 0.55 \mathrm{mmol}, 89 \%$ ) as a colorless highly viscous oil.

The same procedure was repeated with Taxol like protected diol (16ba) ( $300 \mathrm{mg}, 0.47$ mmol ) to afford the Taxol like primary alcohol ( $\mathbf{1 6 b b}$ ) ( $167 \mathrm{mg}, 0.43 \mathrm{mmol}, 90 \%$ ) as a colorless highly viscous oil.

## (4R,5R)-5-((S)-6-(3-Hydroxypropyl)-6-methylcyclohex-1-enyl)-4-(3-methylbut-2-enyl)-4-(2-

 methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (16ab)
${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.82(\mathrm{t}, \mathrm{J}=4.0 \mathrm{~Hz}, 1 \mathrm{H}), 5.29(\mathrm{ddq}, \mathrm{J}=7.7,6.5,1.5 \mathrm{~Hz}, 1 \mathrm{H})$, $5.24(\mathrm{~s}, 1 \mathrm{H}), 3.71-3.58(\mathrm{~m}, 2 \mathrm{H}), 2.72(\mathrm{ddt}, \mathrm{J}=16.2,6.5,1.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.64(\mathrm{dd}, \mathrm{J}=16.2,7.7 \mathrm{~Hz}$, $1 \mathrm{H}), 2.12-2.05(\mathrm{~m}, 2 \mathrm{H}), 1.78(\mathrm{~s}, 3 \mathrm{H}), 1.75-1.71(\mathrm{~m}, 1 \mathrm{H}), 1.69(\mathrm{~d}, \mathrm{~J}=1.3 \mathrm{~Hz}, 3 \mathrm{H}), 1.67-1.63(\mathrm{~m}$,
$2 \mathrm{H}), 1.60-1.53(\mathrm{~m}, 5 \mathrm{H}), 1.53-1.42(\mathrm{~m}, 2 \mathrm{H}), 1.39-1.33(\mathrm{~m}, 2 \mathrm{H}), 1.30(\mathrm{~s}, 3 \mathrm{H}), 1.30(\mathrm{~s}, 3 \mathrm{H}), 1.10(\mathrm{~s}$, 3H).
${ }^{13} \mathbf{C}$ NMR (126 M Hz, $\left.\mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}$ : 155.2, 139.3, 132.6, 132.1, 119.2, 90.0, 83.3, 79.9, 79.5, $63.3,41.8,36.9,36.3,35.5,31.2,27.2,26.2,25.9,25.7,24.9,24.7,18.4,18.0,3.5$.

IR (1/2 $\left.\mathrm{cm}^{-1}\right): 3486,3055,2937,2873,2254,1789,1652,1541,1460,1389,1378,1337,1255$, 1189, 1048.

HRMS (CI, ISO) Calcd for $\left[\mathrm{C}_{24} \mathrm{H}_{37} \mathrm{O}_{4}\right]^{+}: \mathrm{m} / \mathrm{z} 689.2692$, found 389.2689.
$[ \pm]_{\mathrm{D}}^{25}:+16.5\left(\mathrm{c} 1.6, \mathrm{CH}_{2} \mathrm{Cl}_{2}\right)$.
(4S,5S)-5-((S)-6-(3-Hydroxypropyl)-6-methylcyclohex-1-enyl)-4-(3-methylbut-2-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (16bb)

${ }^{1} \mathbf{H} \mathbf{N M R}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.77(\mathrm{t}, \mathrm{J}=4.0 \mathrm{~Hz}, 1 \mathrm{H}), 5.32-5.29(\mathrm{~m}, 2 \mathrm{H}), 3.62(\mathrm{t}, \mathrm{J}=6.1$ $\mathrm{Hz}, 2 \mathrm{H}), 2.70(\mathrm{ddt}, \mathrm{J}=16.2,6.3,1.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.62(\mathrm{dd}, \mathrm{J}=16.2,7.1 \mathrm{~Hz}, 1 \mathrm{H}), 2.15-2.06(\mathrm{~m}, 2 \mathrm{H})$, $1.81(\mathrm{~s}, 3 \mathrm{H}), 1.69(\mathrm{~d}, \mathrm{~J}=1.0 \mathrm{~Hz}, 3 \mathrm{H}), 1.68-1.64(\mathrm{~m}, 1 \mathrm{H}), 1.60-1.54(\mathrm{~m}, 6 \mathrm{H}), 1.54-1.46(\mathrm{~m}, 3 \mathrm{H})$, 1.45-1.35 (m, 2H), $1.31(\mathrm{~s}, 3 \mathrm{H}), 1.30(\mathrm{~s}, 3 \mathrm{H}), 1.13(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR (126 M Hz, CDCl 3 ) $\delta$ ppm: 155.2, 140.9, 132.4, 131.0, 119.1, 90.0, 83.0, 81.0, 79.4, $63.5,41.8,36.4,35.0,34.8,31.2,27.1,25.9,25.8,24.9,24.9,24.8,18.2,18.0,3.6$.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3508, 3059, 2936, 2877, 2254, 1782, 1649, 1541, 1460, 1389, 1378, 1333, 1207, 1189, 1059, 1037.

HRMS (EI) Calcd for $\left[\mathrm{C}_{24} \mathrm{H}_{36} \mathrm{O}_{4}\right]^{+}$: m/z 388.2614, found 388.2608.
$[ \pm]_{\mathrm{D}}^{25}:-10.6\left(\mathrm{c} 2.1, \mathrm{CH}_{2} \mathrm{Cl}_{2}\right)$.




Formula: $\mathrm{C}_{24} \mathrm{H}_{34} \mathrm{O}_{3}$
MW: 370.5
To a solution of primary alcohol (16ab) ( $75 \mathrm{mg}, 0.2 \mathrm{mmol}$ ) in THF ( 7 mL ) was added 0 nitrophenylselenocyanate ( $106 \mathrm{mg}, 0.47 \mathrm{mmol} 2.4$ equiv) and tri-n-butylphosphine ( $117 \mu \mathrm{~L}, 0.47$ mmol 2.4 equiv). The mixture was stirred at room temperature for 20 min . The reaction was quenched with water. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$ and the combined organic extracts were washed with brine, dried over $\mathrm{MgSO}_{4}$, filtered and concentrated in vacuo to give a brown oil that was used without further purification. A solution of ammonium molybdate ( 86 mg ) in water ( 6 mL ) and hydrogen peroxide ( $3 \mathrm{~mL}, 30 \%$ solution) was then prepared. This solution ( 1.7 mL ) was added at $-10^{\circ} \mathrm{C}$ to a solution of the previous compound in THF ( 3 mL ). The mixture was stirred at this temperature for 20 min . The reaction was quenched with water. The aqueous layer was extracted with $\mathrm{Et}_{2} \mathrm{O}$, and the combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{SSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/Et $\mathrm{t}_{2} \mathrm{O}: 95 / 5$ ) to afford the title compound (17a) ( $69 \mathrm{mg}, 0.19 \mathrm{mmol}, 93 \%$ ) as a pale yellow viscous oil.

The same procedure was repeated with Taxol like primary alcohol (16bb) (100 mg, 0.26 mmol ) to afford (17b) ( $86 \mathrm{mg}, 0.23 \mathrm{mmol}, 89 \%$ ) as a pale yellow viscous oil.
(4R,5R)-5-((S)-6-Allyl-6-methylcyclohex-1-enyl)-4-(3-methylbut-2-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one (17a)

${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.82-5.71(\mathrm{~m}, 2 \mathrm{H}), 5.31-5.25(\mathrm{~m}, 2 \mathrm{H}), 5.11-5.03(\mathrm{~m}, 2 \mathrm{H})$, $2.70(\mathrm{ddt}, \mathrm{J}=16.1,6.3,1.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.63(\mathrm{dd}, \mathrm{J}=16.1,7.1 \mathrm{~Hz}, 1 \mathrm{H}), 2.39(\mathrm{dd}, \mathrm{J}=14.1,6.6 \mathrm{~Hz}$, 1H), 2.16-2.05 (m, 3H), 1.79 ( $\mathrm{s}, 3 \mathrm{H}$ ), 1.69 ( $\mathrm{d}, \mathrm{J}=1.0 \mathrm{~Hz}, 3 \mathrm{H}$ ), 1.67-1.61 (m, 2H), 1.61-1.55 (m, 1 H ), 1.59 ( $\mathrm{s}, 3 \mathrm{H}$ ), 1.37-1.33 (m, 1H), 1.31 ( $\mathrm{s}, 3 \mathrm{H}$ ), 1.31 ( $\mathrm{s}, 3 \mathrm{H}$ ), $1.10(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta \mathrm{ppm}$ : 155.3, 139.1, 134.1, 132.5, 132.1, 119.2, 117.9, 89.9, 83.2, 80.1, 79.5, 44.7, 41.7, 36.8, 35.6, 31.1, 25.8, 25.7, 25.5, 24.9, 24.7, 18.1, 18.0, 3.6.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3077, 2977, 2936, 2877, 2254, 1790, 1649, 1638, 1460, 1389, 1378, 1333, 1252, 1188, 1048.

HRMS (ESI) Calcd for [ $\left.\mathrm{C}_{24} \mathrm{H}_{34} \mathrm{O}_{3} \mathrm{Na}\right]^{+}: \mathrm{m} / \mathrm{z} 393.2400$, found 393.2385 .
$[ \pm]^{26}{ }_{\mathrm{D}}:+17.6\left(\mathrm{c} 1.4, \mathrm{CH}_{2} \mathrm{Cl}_{2}\right)$.
(4S,5S)-5-((S)-6-Allyl-6-methylcyclohex-1-enyl)-4-(3-methylbut-2-enyl)-4-(2-methylpent-3-yn-2-yl)-1,3-dioxolan-2-one(17b)

${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.83-5.73(\mathrm{~m}, 2 \mathrm{H}), 5.35-5.29(\mathrm{~m}, 2 \mathrm{H}), 5.11-5.01(\mathrm{~m}, 2 \mathrm{H})$, 2.74 (ddt, J = 16.1, 6.2, 1.4 Hz, 1H), $2.67(\mathrm{dd}, \mathrm{J}=16.1,7.1 \mathrm{~Hz}, 1 \mathrm{H}), 2.34(\mathrm{dd}, \mathrm{J}=13.5,6.8 \mathrm{~Hz}$, $1 \mathrm{H}), 2.18-2.08(\mathrm{~m}, 3 \mathrm{H}), 1.77(\mathrm{~s}, 3 \mathrm{H}), 1.70(\mathrm{~d}, \mathrm{~J}=1.2 \mathrm{~Hz}, 3 \mathrm{H}), 1.68-1.62(\mathrm{~m}, 1 \mathrm{H}), 1.62-1.56(\mathrm{~m}$, 2 H ), 1.60 ( $\mathrm{s}, 3 \mathrm{H}$ ), 1.37 (ddd, J = 12.5, 8.8, 3.5 Hz, 1H), 1.31 ( $\mathrm{s}, 3 \mathrm{H}), 1.31(\mathrm{~s}, 3 \mathrm{H}), 1.14(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $126 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}$ ) $\delta$ ppm: 155.2, 140.7, 134.3, 132.4, 131.6, 119.1, 117.9, 89.8, 83.1, $80.5,79.4,43.5,41.7,36.9,34.8,31.2,25.9,25.8,24.9,24.9,24.6,18.1,18.0,3.5$.

IR (1⁄2 $\mathrm{cm}^{-1}$ ): 3156, 3077, 2980, 2933, 2876, 2254, 1786, 1643, 1463, 1380, 1330, 1201, 1190, 1064, 1046.

HRMS (ESI) Calcd for [ $\left.\mathrm{C}_{24} \mathrm{H}_{34} \mathrm{O}_{3} \mathrm{Na}\right]^{+}: \mathrm{m} / \mathrm{z} 393.2400$, found 393.2389 .
$[ \pm]^{24}{ }_{\mathrm{D}}:-6.2\left(\mathrm{C} .1 .35, \mathrm{CHCl}_{3}\right)$.

## (Z)-(6-(1,1-Dimethyl-but-2-ynyl)-11-methyl-3,5-dioxa-tricyclo[9.4.0.0 ${ }^{2,6}$ ]pentadeca-1(15),8-

 dien-4-one (18a) and (18b)

Formula: $\mathrm{C}_{20} \mathrm{H}_{26} \mathrm{O}_{3}$
MW: 314.4
A solution of (15a) (18 mg, $51 \mu \mathrm{~mol})$ in toluene ( 5 mL ) was thoroughly degassed (using the freeze-thaw pump technique) and second-generation Grubbs' catalyst ( $3.5 \mathrm{mg}, 4.0 \mu \mathrm{~mol}$, 0.05 equiv) was added and the mixture was stirred at reflux for 6 h . At that time secondgeneration Grubbs' catalyst ( $3.5 \mathrm{mg}, 4.0 \mu \mathrm{~mol}, 0.05$ equiv) was added and the mixture was stirred at reflux for 16 h . A fter cooling, the solvent was removed in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/ $\mathrm{Et}_{2} \mathrm{O}$ : 95/5) to afford the title compound (18a) ( $10 \mathrm{mg}, 63 \%$ ) as a white solid.

The same procedure repeated with (15b) ( $20 \mathrm{mg}, 56 \mu \mathrm{~mol}$ ) afforded the triene (18b) (12 $\mathrm{mg}, 68 \%$ ) as a colorless oil.

## (Z)-(2R,6R,11R)-6-(1,1-Dimethyl-but-2-ynyl)-11-methyl-3,5-dioxatricyclo[9,4.0.0 ${ }^{2,6}$ ] pentadeca-1(15),8-dien-4-one (18a)


M.p.: $144^{\circ} \mathrm{C}$.
${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.95-5.87(\mathrm{~m}, 2 \mathrm{H}), 5.68-5.61(\mathrm{~m}, 1 \mathrm{H}), 5.57(\mathrm{~s}, 1 \mathrm{H}), 2.56-$ $2.45(\mathrm{~m}, 3 \mathrm{H}), 2.25-2.16(\mathrm{~m}, 1 \mathrm{H}), 2.11(\mathrm{ddt}, \mathrm{J}=18.9,7.1,3.9 \mathrm{~Hz}, 1 \mathrm{H}), 1.90(\mathrm{dd}, \mathrm{J}=13.7,8.1 \mathrm{~Hz}$,
$1 \mathrm{H}), 1.79(\mathrm{~s}, 3 \mathrm{H}), 1.76-1.65(\mathrm{~m}, 2 \mathrm{H}), 1.64-1.58(\mathrm{~m}, 1 \mathrm{H}), 1.57-1.50(\mathrm{~m}, 1 \mathrm{H}), 1.38(\mathrm{~s}, 3 \mathrm{H}), 1.25(\mathrm{~s}$, $3 \mathrm{H}), 1.19(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR (126 M Hz, CDCl 3 ) $\delta$ ppm: 154.0, 139.4, 135.3, 131.7, 125.6, 91.9, 90.0, 81.9, 79.5, $42.4,42.0,40.8,39.3,28.0,27.2,26.4,24.9,24.5,17.7,3.5$.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3033, 2986, 2940, 2874, 2254, 1786, 1630, 1461, 1390, 1378, 1353, 1309, 1259, 1280, 1203, 1059.

HRMS (EI) Calcd for $\left[\mathrm{C}_{20} \mathrm{H}_{26} \mathrm{O}_{3}\right]^{+}$: m/z 314.1882, found 314.1881.
$\left.\mathrm{E}_{\mathrm{t}}\right]_{\mathrm{D}}^{25}:+131\left(\mathrm{C} 0.46, \mathrm{CHCl}_{3}\right)$.

## (Z)-(2R,6R,11S)-6-(1,1-Dimethyl-but-2-ynyl)-11-methyl-3,5-dioxa-

 tricyclo[9.4.0.0 ${ }^{2,6}$ ]pentadeca-1(15),8-dien-4-one (18b)
M.p.: $80^{\circ} \mathrm{C}$.
${ }^{1} \mathbf{H} \mathbf{N M R}\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.75(\mathrm{~m}, 3 \mathrm{H}), 5.39(\mathrm{brs}, 1 \mathrm{H}), 2.62-2.48(\mathrm{~m}, 3 \mathrm{H}), 2.29-2.21$ $(\mathrm{m}, 2 \mathrm{H}), 1.92-1.81(\mathrm{~m}, 2 \mathrm{H}), 1.74(\mathrm{~s}, 3 \mathrm{H}), 1.65-1.72(\mathrm{~m}, 1 \mathrm{H}), 1.58-1.54(\mathrm{~m}, 2 \mathrm{H}), 1.40(\mathrm{~s}, 3 \mathrm{H})$, $1.34(\mathrm{~s}, 3 \mathrm{H}), 1.11(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR (126 M Hz, CDCl $\left.{ }_{3}\right) \delta \mathrm{ppm}: 155.1,139.4,129.6,127.0,126.5,91.0,83.3,80.9,80.7$, $41.7,40.0,39.2,39.2,31.8,25.7,25.0,24.9,23.8,17.3,3.7$.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3032, 2981, 2928, 2875, 2855, 2253, 1791, 1643, 1461, 1381, 1332, 1261, 1185, 1127, 1100, 1052, 1037.

HRMS (CI, ISO) Calcd for $\left[\mathrm{C}_{20} \mathrm{H}_{27} \mathrm{O}_{3}\right]^{+}: \mathrm{m} / \mathrm{z} 315.1960$, found 315.1965.
$[ \pm]_{\mathrm{D}}^{25}:+109\left(\mathrm{C} 0.74, \mathrm{CHCl}_{3}\right)$.

## benzoate (19a) and (19b)



Formula: $\mathrm{C}_{29} \mathrm{H}_{38} \mathrm{O}_{3}$
MW: 434.6
To a solution of triene (15a) ( $20 \mathrm{mg}, 56 \mu \mathrm{~mol}$ ) in THF ( 3 mL ) at $-78^{\circ} \mathrm{C}$ was added phenyllithium ( $330 \mu \mathrm{~L}, 1.5 \mathrm{M}$ in $\mathrm{Et}_{2} \mathrm{O}, 0.5 \mathrm{mmol}, 9.0$ equiv). The mixture was stirred at this temperature for 3 h . Saturated aqueous $\mathrm{NaHCO}_{3}$ was then added, and the aqueous phase was extracted with $\mathrm{Et}_{2} \mathrm{O}$. The combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{SSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography on silica gel (diethyl ether/petroleum ether: 5/95) to afford (19a) (23 mg, $94 \%, E / Z=3: 1$ ) as a pale yellow oil.

The same procedure repeated with (15b) ( $25 \mathrm{mg}, 80 \mu \mathrm{~mol}$ ) afforded the benzoate (19b) ( $31 \mathrm{mg}, 91 \%$ ) as a colorless oil.

## (1R*, 2R*)-1-((S*)-6-Allyl-6-methylcyclohex-1-enyl)-2-hydroxy-2-(2-methyl-pent-3-yn-2-yl)hex-4-enyl benzoate (19a)


${ }^{1} \mathbf{H} \operatorname{NM} \mathbf{R}\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 8.07(\mathrm{~d}, \mathrm{~J}=7.2 \mathrm{~Hz}, 2 \mathrm{H}), 7.54(\mathrm{t}, \mathrm{J}=7.2 \mathrm{~Hz}, 1 \mathrm{H}), 7.44(\mathrm{t}, \mathrm{J}=$ $7.7 \mathrm{~Hz}, 2 \mathrm{H}), 6.53(\mathrm{t}, \mathrm{J}=3.9 \mathrm{~Hz}, 1 \mathrm{H}), 5.97(\mathrm{~s}, 1 \mathrm{H}), 5.66(\mathrm{~m}, 2 \mathrm{H}), 5.39(\mathrm{dq}, \mathrm{J}=12.9,6.4 \mathrm{~Hz}, 1 \mathrm{H})$,
$4.95(\mathrm{~m}, 2 \mathrm{H}), 2.49(\mathrm{~d}, \mathrm{~J}=6.7 \mathrm{~Hz}, 2 \mathrm{H}), 2.36(\mathrm{~m}, 1 \mathrm{H}), 2.13(\mathrm{~m}, 3 \mathrm{H}), 1.70(\mathrm{dd}, \mathrm{J}=6.3,0.9 \mathrm{~Hz}$, $3 \mathrm{H}), 1.47-1.65(\mathrm{~m}, 4 \mathrm{H}), 1.35(\mathrm{~s}, 3 \mathrm{H}), 1.27(\mathrm{~s}, 3 \mathrm{H}), 1.25(\mathrm{~s}, 3 \mathrm{H}), 1.12(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $\left.126 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 165.0,142.3,135.3,132.7,131.5,131.3,130.0,128.4$, $127.9,126.8,117.1,85.0,78.8,78.5,72.5,44.1,42.1,37.1,36.3,35.1,27.5,25.9,25.4,25.2$, 18.3, 18.2, 3.4.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3550, 3074, 2934, 2755, 1761, 1719, 1669, 1637, 1450, 1384, 1315, 1268, 1200, 1176, 1113, 1069, 1026, 998, 973, 909.

HRMS (ESI) Calcd. for [ $\mathrm{C}_{29} \mathrm{H}_{38} \mathrm{O}_{3}$ ]: 434.2821, found: 434.2811 .

## (1R*, 2R*)-1-((R*)-6-Allyl-6-methylcyclohex-1-enyl)-2-hydroxy-2-(2-methyl-pent-3-yn-2-yl)hex-4-enyl benzoate (19b)



[^2]${ }^{13} \mathbf{C}$ NMR ( $\left.126 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 165.3,142.6,135.2,132.8,131.4,131.3,130.0,128.4$, $127.8,127.0,117.5,85.1,78.9,78.5,73.7,44.2,42.1,37.0,35.8,32.0,27.4,26.0,25.7,25.4$, 18.3, 18.2, 3.4.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3550, 2960, 2930, 2873, 1720, 1602, 1451, 1379, 1315, 1268, 1176, 1112, 1069, 1026.

HRMS (EI) Calcd. for [ $\mathrm{C}_{29} \mathrm{H}_{38} \mathrm{O}_{3}$ ]: 434.2821, found: 434.2816.

## 6-Hydroxy-10a-methyl-6-(2-methylpent-3-yn-2yl)-1,2,3,5,6,7,10,10a-octahydrobenzo <br> [8]annulen-5-yl benzoate (20a) and (20b)



Formula: $\mathrm{C}_{26} \mathrm{H}_{32} \mathrm{O}_{3}$
M W: 392.5
A solution of benzoate (19a) ( $16 \mathrm{mg}, 39 \mu \mathrm{~mol}$ ) in toluene ( 15 mL ) was thoroughly degassed (using the freeze-thaw pump technique) and second-generation Grubbs' catalyst ( 5 mg , $6 \mu \mathrm{~mol}, 0.05$ equiv) was added and the mixture was stirred at reflux for 6 h . At that time secondgeneration Grubbs' catalyst ( $5 \mathrm{mg}, 6 \mu \mathrm{~mol}, 0.05$ equiv) was added and the mixture was stirred at reflux for 16 h . A fter cooling, the solvent was removed in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/Et 2 O : 95/5) to afford the title compound (20a) (12 mg, 78\%) as a colorless oil.

The same procedure was repeated with (19b) ( $10 \mathrm{mg}, 23 \mu \mathrm{~mol}$ ) to afford the title compound (20b) ( $6 \mathrm{mg}, 83 \%$ ) as a colorless oil.
(5R,6R,10aS)-6-H ydroxy-10a-methyl-6-(2-methylpent-3-yn-2yl)-1,2,3,5,6,7,10,10a-octahydrobenzo[8]annulen-5-yl benzoate (20a)

${ }^{1} \mathbf{H}$ NM R $\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 8.15(\mathrm{dd}, \mathrm{J}=8.2,1.1 \mathrm{~Hz}, 2 \mathrm{H}), 7.61-7.56(\mathrm{~m}, 1 \mathrm{H}), 7.50-7.46$ ( $\mathrm{m}, 2 \mathrm{H}$ ) , 6.19 (brs, 1H), 6.02 (brs, 1H), $5.79(\mathrm{dt}, \mathrm{J}=11.2,8.1 \mathrm{~Hz}, 1 \mathrm{H}), 5.67-5.59(\mathrm{~m}, 1 \mathrm{H}), 3.25$ (dd, J = 13.4, 8.3 Hz, 1H), $2.81(d d, J=15.8,7.9 \mathrm{~Hz}, 1 \mathrm{H}), 2.50(\mathrm{~s}, 1 \mathrm{H}), 2.32(\mathrm{dd}, \mathrm{J}=15.8,5.6$ $\mathrm{Hz}, 1 \mathrm{H}), 2.21-2.14(\mathrm{~m}, 1 \mathrm{H}), 2.04-1.96(\mathrm{~m}, 1 \mathrm{H}), 1.83-1.74(\mathrm{~m}, 3 \mathrm{H}), 1.71(\mathrm{~s}, 3 \mathrm{H}), 1.64-1.60(\mathrm{~m}$, $1 \mathrm{H}), 1.34(\mathrm{~s}, 3 \mathrm{H}), 1.34(\mathrm{~s}, 3 \mathrm{H}), 1.30-1.28(\mathrm{~m}, 1 \mathrm{H}), 1.03(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta \mathrm{ppm}$ : 165.8, 140.5, 133.1, 133.0, 130.6, 129.8, 129.7, 128.5, 127.0, 84.8, 83.0, 80.1, 79.1, 41.5, 40.1, 38.3, 37.3, 30.5, 29.7, 26.6, 26.3, 25.5, 18.3, 3.7.

IR (1⁄2 $\mathrm{cm}^{-1}$ ): 3602, 3070, 3020, 2977, 2924, 2874, 2402, 1714, 1605, 1523, 1453, 1275, 1219, 1116, 1099, 1070, 1027.

HRMS (CI, ISO) Calcd for $\left[\mathrm{C}_{26} \mathrm{H}_{33} \mathrm{O}_{3}\right]^{\dagger}: \mathrm{m} / \mathrm{z} 393.2430$, found 393.2435 .
$[ \pm]^{25}$ : $+80.8\left(\mathrm{C} 0.58, \mathrm{CHCl}_{3}\right)$.
(55,65,10aS)-6-Hydroxy-10a-methyl-6-(2-methylpent-3-yn-2yl)-1,2,3,5,6,7,10,10a-octa hydrobenzo[8]annulen-5-yl benzoate (20b)

${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 8.10-8.05(\mathrm{~m}, 2 \mathrm{H}), 7.57-7.52(\mathrm{~m}, 1 \mathrm{H}), 7.47-7.42(\mathrm{~m}, 2 \mathrm{H})$, 6.21 (dd, J = 4.4, 3.3 Hz, 1H), $5.99(\mathrm{~s}, 1 \mathrm{H}), 5.87-5.82(\mathrm{~m}, 1 \mathrm{H}), 5.68(\mathrm{tdd}, \mathrm{J}=10.9,6.3,1.7 \mathrm{~Hz}$, 1H), $2.84(\mathrm{~s}, 1 \mathrm{H}), 2.65(\mathrm{dd}, \mathrm{J}=13.1,6.7 \mathrm{~Hz}, 1 \mathrm{H}), 2.55(\mathrm{dd}, \mathrm{J}=13.1,11.7 \mathrm{~Hz}, 1 \mathrm{H}), 2.27(\mathrm{dd}, \mathrm{J}=$ $13.2,6.3 \mathrm{~Hz}, 1 \mathrm{H}), 2.25-2.18(\mathrm{~m}, 1 \mathrm{H}), 2.08-1.99(\mathrm{~m}, 1 \mathrm{H}), 1.79-1.71(\mathrm{~m}, 2 \mathrm{H}), 1.61-1.55(\mathrm{~m}, 2 \mathrm{H})$, 1.53-1.47 (m, 1H), 1.37 ( $\mathrm{s}, 3 \mathrm{H}$ ), 1.36 ( $\mathrm{s}, 3 \mathrm{H}), 1.32(\mathrm{~s}, 3 \mathrm{H}), 1.25(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta \mathrm{ppm}: 164.3,142.6,132.6,131.2,130.4,129.9,129.4,128.2$, 127.4, 85.2, 79.4, 78.5, 72.4, 41.4, 40.4, 39.7, 39.1, 33.6, 28.0, 26.4, 26.1, 25.9, 18.4, 3.3.

IR (1⁄2 $\mathrm{cm}^{-1}$ ): 3530, 3155, 3026, 2978, 2933, 2872, 2253, 1713, 1604, 1469, 1453, 1386, 1319, 1277, 1177, 1119.

HRMS (EI) Calcd for $\left[\mathrm{C}_{26} \mathrm{H}_{33} \mathrm{O}_{3}\right]^{+}: \mathrm{m} / \mathrm{z} 392.2351$, found 392.2352 .
$[ \pm]^{25}{ }_{\mathrm{D}}:+163.4\left(\mathrm{c} 1.48, \mathrm{CHCl}_{3}\right)$.

## 4-enyl benzoate (21a) and (21b)



Formula: $\mathrm{C}_{30} \mathrm{H}_{40} \mathrm{O}_{3}$
M W : 448.6
To a solution of (17a) ( $56 \mathrm{mg}, 0.15 \mathrm{mmol}$ ) in THF ( 5 mL ) at $-78^{\circ} \mathrm{C}$ was added phenyllithium ( $1.15 \mathrm{~mL}, 0.8 \mathrm{M}$ in $\mathrm{nBu}_{2} \mathrm{O}, 1.43 \mathrm{mmol}, 9.0$ equiv). The mixture was stirred at this temperature for 1.5 h . A solution of saturated aqueous $\mathrm{NaHCO}_{3}$ was then added and the aqueous phase was extracted with $\mathrm{Et}_{2} \mathrm{O}$. The combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{gSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/Et $\mathrm{t}_{2} \mathrm{O}$ : 95/5) to afford the title benzoate (21a) ( 58 mg , $0.13 \mathrm{mmol}, 83 \%$ ) as a pale yellow viscous oil.

The same procedure was repeated with (17b) ( $27 \mathrm{mg}, 73 \mu \mathrm{~mol}$ ) to afford the title benzoate (21b) ( $30 \mathrm{mg}, 68 \mu \mathrm{~mol}, 93 \%$ ) as a pale yellow viscous oil.

## (1R,2R)-1-((S)-6-Allyl-6-methylcyclohex-1-enyl)-2-hydroxy-5-methyl-2-(2-methylpent-3-yn-2-yl)hex-4-enyl benzoate (21a)


${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 8.07(\mathrm{dd}, \mathrm{J}=8.2,1.2 \mathrm{~Hz}, 2 \mathrm{H}), 7.57-7.51(\mathrm{~m}, 1 \mathrm{H}), 7.41-7.40$ $(\mathrm{m}, 2 \mathrm{H}), 6.52(\mathrm{t}, \mathrm{J}=4.0 \mathrm{~Hz}, 1 \mathrm{H}), 5.99(\mathrm{~s}, 1 \mathrm{H}), 5.68(\mathrm{ddt}, \mathrm{J}=17.2,10.0,7.3 \mathrm{~Hz}, 1 \mathrm{H}), 5.44(\mathrm{ddq}, \mathrm{J}$ $=8.1,6.8,1.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.00-4.92(\mathrm{~m}, 2 \mathrm{H}), 2.88(\mathrm{~s}, 1 \mathrm{H}), 2.54-2.38(\mathrm{~m}, 3 \mathrm{H}), 2.17-2.08(\mathrm{~m}, 3 \mathrm{H})$, $1.74(\mathrm{~d}, \mathrm{~J}=0.9 \mathrm{~Hz}, 3 \mathrm{H}), 1.66-1.58(\mathrm{~m}, 2 \mathrm{H}), 1.61(\mathrm{~s}, 3 \mathrm{H}), 1.54-1.48(\mathrm{~m}, 1 \mathrm{H}), 1.37(\mathrm{~s}, 3 \mathrm{H}), 1.35-$ $1.29(\mathrm{~m}, 1 \mathrm{H}), 1.27(\mathrm{~s}, 3 \mathrm{H}), 1.25(\mathrm{~s}, 3 \mathrm{H}), 1.12(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13} \mathbf{C}$ NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta \mathrm{ppm}$ : 164.9, 142.7, 135.2, 132.6, 131.5, 131.3, 131.2, 129.9, 128.3, 120.9, 117.0, 85.1, 78.9, 78.6, 72.5, 44.0, 42.0, 36.9, 35.0, 32.3, 27.6, 26.1, 25.8, 25.3, 25.3, 18.1, 18.0, 3.2.

IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3539, 3155, 3065, 2973, 2933, 2253, 1709, 1602, 1450, 1382, 1317, 1272, 1216, 1177, 1095, 1070.

HRMS (ESI) Calcd for [C $\left.\mathrm{C}_{30} \mathrm{H}_{40} \mathrm{O}_{3} \mathrm{Na}\right]^{+}: \mathrm{m} / \mathrm{z} 471.2870$, found 471. 2852.
$[ \pm]^{25}$ : -12.3 ( $\mathrm{C} 0.5 \mathrm{CHCl}_{3}$ ).
(1S,2S)-1-((S)-6-Allyl-6-methylcyclohex-1-enyl)-2-hydroxy-5-methyl-2-(2-methylpent-3-yn-2-yl)hex-4-enyl benzoate (21b)

${ }^{1} \mathbf{H} \mathbf{N M R}\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 8.07(\mathrm{dd}, \mathrm{J}=8.2,1.2 \mathrm{~Hz}, 2 \mathrm{H}), 7.57-7.51(\mathrm{~m}, 1 \mathrm{H}), 7.47-7.40$ $(\mathrm{m}, 2 \mathrm{H}), 6.49(\mathrm{t}, \mathrm{J}=3.9 \mathrm{~Hz}, 1 \mathrm{H}), 6.00(\mathrm{~s}, 1 \mathrm{H}), 5.84(\mathrm{~m}, 1 \mathrm{H}), 5.44(\mathrm{tt}, \mathrm{J}=6.8,1.3 \mathrm{~Hz}, 1 \mathrm{H}), 5.08-$ $5.01(\mathrm{~m}, 2 \mathrm{H}), 2.89(\mathrm{~s}, 1 \mathrm{H}), 2.53(\mathrm{dd}, \mathrm{J}=15.8,7.3 \mathrm{~Hz}, 1 \mathrm{H}), 2.49-2.40(\mathrm{~m}, 2 \mathrm{H}), 2.18(\mathrm{dd}, \mathrm{J}=13.2$, $7.8 \mathrm{~Hz}, 1 \mathrm{H}), 2.13-2.07(\mathrm{~m}, 2 \mathrm{H}), 1.74(\mathrm{~d}, \mathrm{~J}=0.9 \mathrm{~Hz}, 3 \mathrm{H}), 1.61(\mathrm{~s}, 3 \mathrm{H}), 1.59-1.53(\mathrm{~m}, 3 \mathrm{H}), 1.43-$ $1.39(\mathrm{~m}, 1 \mathrm{H}), 1.38(\mathrm{~s}, 3 \mathrm{H}) 1.29(\mathrm{~s}, 3 \mathrm{H}), 1.27(\mathrm{~s}, 3 \mathrm{H}), 1.09(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ ppm: 165.0, 142.8, 135.1, 132.6, 131.7, 131.2, 131.1, 129.8, 128.3, 120.7, 117.3, 85.2, 78.8, 78.6, 73.5, 44.2, 42.0, 36.9, 35.7, 32.6, 27.5, 26.1, 25.9, 25.6, 25.4, 18.0, 18.0, 3.3.

IR (1⁄2 $\left.\mathrm{cm}^{-1}\right): 3542,3154,2976,2932,2253,1711,1452,1382,1316,1271,1177,1113,995$.
HRMS (EI) Calcd for $\left[\mathrm{C}_{30} \mathrm{H}_{40} \mathrm{O}_{3}\right]^{+}: \mathrm{m} / \mathrm{z} 448.2977$, found 448.2973.
$[ \pm]^{25}{ }_{\mathrm{D}}:+23.6\left(\mathrm{c} 1.8, \mathrm{CHCl}_{3}\right)$.
(1R,5R,8Z,11S)-11-M ethyl-6-(2-methylpent-3-yn-2-yl)-3,5-dioxatricyclo[9.4.0]pentadeca-1(15),8dien-4-one (18a)


A solution of (17a) ( $30 \mathrm{mg}, 80 \mu \mathrm{~mol}$ ) in toluene ( 25 mL ) was thoroughly degassed (using the freeze-thaw pump technique) and second-generation Grubbs' catalyst ( $3.5 \mathrm{mg}, 4.0 \mu \mathrm{~mol}$, 0.05 equiv) was added and the mixture was stirred at reflux for 6 h . At that time secondgeneration Grubbs' catalyst ( $3.5 \mathrm{mg}, 4.0 \mu \mathrm{~mol}, 0.05$ equiv) was added and the mixture was stirred at reflux for 16 h . A fter cooling, the solvent was removed in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/Et $\mathrm{t}_{2} \mathrm{O}$ : 95/5) to afford the title compound (18a) ( $20 \mathrm{mg}, 63 \mu \mathrm{~mol}, 79 \%$ ) as a white solid.

## 6-H ydroxy-10a-methyl-6-(2-methylpent-3-yn-2yl)-1,2,3,5,6,7,10,10a-octahydrobenzo [8]annulen-5-yl benzoate (20a) and (20b)





A solution of benzoate (21a) ( $53 \mathrm{mg}, 0.12 \mathrm{mmol}$ ) in toluene ( 15 mL ) was thoroughly degassed (using the freeze-thaw pump technique) and second-generation Grubbs' catalyst ( 5 mg , $6 \mu \mathrm{~mol}, 0.05$ equiv) was added and the mixture was stirred at reflux for 6 h . At that time secondgeneration Grubbs' catalyst ( $5 \mathrm{mg}, 6 \mu \mathrm{~mol}, 0.05$ equiv) was added and the mixture was stirred at reflux for 16 h . A fter cooling, the solvent was removed in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/ $/ \mathrm{Et}_{2} \mathrm{O}$ : 95/5) to afford the title compound (20a) ( $37 \mathrm{mg}, 96 \mu \mathrm{~mol}, 80 \%$ ) as a colourless oil.

The same procedure was repeated with (21b) ( $11 \mathrm{mg}, 25 \mu \mathrm{~mol}$ ) to afford the title compound (20b) ( $8.8 \mathrm{mg}, 23 \mu \mathrm{~mol}, 90 \%$ ) as a colorless oil.
(1S,5S,11S)-11,15,18,18-T etramethyl-2,4-dioxatetracyclo[12.3.1.0]octadeca-6,13,15-trien-3one (22) and (18b)




Formula: $\mathrm{C}_{20} \mathrm{H}_{26} \mathrm{O}_{3}$

A solution of (17b) ( $37 \mathrm{mg}, 0.1 \mathrm{mmol}$ ) in toluene ( 33 mL ) was thoroughly degassed under argon (using the freeze-thaw pump technique) and $\mathrm{Zhan-1B}$ catalyst ( $7 \mathrm{mg}, 10 \mu \mathrm{~mol}, 0.1$ equiv) was added and the mixture was stirred at reflux for 24 h . The resulting mixture was allowed to cool down and the solvent was removed in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/ $\mathrm{Et}_{2} \mathrm{O}$ : 95/5) to afford the title tricycle compound (22) (22 mg, $70 \mu \mathrm{~mol}, 75 \%$ ) as a colorless oil and (17b) ( $6.3 \mathrm{mg}, 20 \mu \mathrm{~mol}, 20 \%$ ) as a white solid.
(1S,5S,11S)-11,15,18,18-T etramethyl-2,4-dioxatetracyclo[12.3.1.0]octadeca-6,13,15-trien-3one (22)

${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.97(\mathrm{dd}, \mathrm{J}=5.5,2.3 \mathrm{~Hz}, 1 \mathrm{H}), 5.73(\mathrm{dd}, \mathrm{J}=13.2,6.2 \mathrm{~Hz}$, $1 \mathrm{H}), 5.13(\mathrm{~s}, 1 \mathrm{H}), 4.98(\mathrm{~m}, 1 \mathrm{H}), 2.83$ (dquin, J $=18.8,2.0 \mathrm{~Hz}, 1 \mathrm{H}), 2.70(\mathrm{t}, \mathrm{J}=13.2 \mathrm{~Hz}, 1 \mathrm{H})$, 2.19 (dquin, J = 18.8, $2.5 \mathrm{~Hz}, 1 \mathrm{H}$ ), 2.09 (dtd, J = 18.1, $5.5,1.6 \mathrm{~Hz}, 1 \mathrm{H}$ ), 1.98 (dd, J = 13.2, 6.2 $\mathrm{Hz}, 1 \mathrm{H}), 1.95-1.86(\mathrm{~m}, 1 \mathrm{H}), 1.80(\mathrm{~m}, 3 \mathrm{H}), 1.75(\mathrm{dd}, \mathrm{J}=13.2,3.6 \mathrm{~Hz}, 1 \mathrm{H}), 1.72-1.66(\mathrm{~m}, 1 \mathrm{H})$, $1.65-1.60(\mathrm{~m}, 1 \mathrm{H}), 1.58(\mathrm{~s}, 3 \mathrm{H}), 1.48-1.43(\mathrm{~m}, 1 \mathrm{H}), 1.34(\mathrm{~s}, 3 \mathrm{H}), 1.18(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta$ ppm: 154.4, 146.2, 138.1, 134.7, 129.1, 127.5, 115.9, 93.4, 79.4, $42.1,41.1,39.2,35.4,30.6,27.2,25.2,24.9,21.3,18.9,18.6$.

IR (1/2 $\left.\mathrm{cm}^{-1}\right)$ : $3025,2938,2872,1704,1454,1433,1395,1378,1275,1218,1188,1025,1003$.
HRMS (EI) Calcd for $\left[\mathrm{C}_{20} \mathrm{H}_{26} \mathrm{O}_{3}\right]^{+}: \mathrm{m} / \mathrm{z} 314.1882$, found 314.1879.

## [(1S,2S,8S,10Z)-8,12,15,15-tetramethyltricyclo[9.3.1.0]pentadeca-3,10,12-triene-1,2-diol (22a)



Formula: $\mathrm{C}_{19} \mathrm{H}_{28} \mathrm{O}_{2}$
M W: 288.4
To a solution of tricycle (22) ( $30 \mathrm{mg}, 95 \mu \mathrm{~mol}$ ) in 1,4-dioxane ( 4 mL ) at $0^{\circ} \mathrm{C}$ was added a solution of 2 N aqueous $\mathrm{NaOH}(2 \mathrm{~mL})$. The reaction mixture was allowed to stir at rt for 2 days. A solution of saturated aqueous $\mathrm{NH}_{4} \mathrm{Cl}$ was then added and the aqueous phase was extracted with $\mathrm{Et}_{2} \mathrm{O}$. The combined organic extracts were washed with brine, dried over anhydrous $\mathrm{MgSO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/Et $\mathrm{t}_{2} \mathrm{O}: 8 / 2$ ) to afford the title diol (22a) ( $22 \mathrm{mg}, 80 \%$ ) as a white solid.
${ }^{1} \mathbf{H} \operatorname{NMR}\left(400 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.89(\mathrm{dd}, \mathrm{J}=5.6,2.8 \mathrm{~Hz}, 1 \mathrm{H}), 5.67(\mathrm{dd}, \mathrm{J}=12.7,6.5 \mathrm{~Hz}$, $1 \mathrm{H}), 4.98(\mathrm{~m}, 1 \mathrm{H}), 4.38(\mathrm{br} . \mathrm{s}, 1 \mathrm{H}), 2.91(\mathrm{dd}, \mathrm{J}=12.7,12.5 \mathrm{~Hz}, 1 \mathrm{H}), 2.87-2.80(\mathrm{~m}, 1 \mathrm{H}), 2.53(\mathrm{~s}$, $1 \mathrm{H}), 2.10(\mathrm{~d}, \mathrm{~J}=1.4 \mathrm{~Hz}, 1 \mathrm{H}), 2.03-1.88(\mathrm{~m}, 3 \mathrm{H}), 1.82-1.70(\mathrm{~m}, 5 \mathrm{H}), 1.56-1.48(\mathrm{~m}, 2 \mathrm{H}), 1.47(\mathrm{~s}$, 3H), 1.27-1.22 (m, 4H), $1.20(\mathrm{~s}, 3 \mathrm{H})$.
${ }^{13}$ C NMR ( $\left.100 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}$ : 149.4, 145.0, 136.5, 125.7, 124.7, 118.3, 81.4, 71.7, 42.9, $42.6,40.3,39.2,33.2,26.6,25.9,25.9,22.8,19.5,18.5$.




Formula: $\mathrm{C}_{26} \mathrm{H}_{31} \mathrm{NO}_{5}$
MW: 437.5
To a solution of diol (22a) ( $22 \mathrm{mg}, 76 \mu \mathrm{~mol}$ ) in dichloromethane ( 2 mL ) were added triethylamine ( $26 \mu \mathrm{~L}, 0.19 \mathrm{mmol}, 2.5$ equiv), DMAP ( $9.6 \mathrm{mg}, 76 \mu \mathrm{~mol}, 1$ equiv) and 4 nitrobenzoyl chloride ( $28 \mathrm{mg}, 0.15 \mathrm{mmol}, 2$ equiv). The reaction mixture was allowed to stir at rt for 16 h . A solution of saturated aqueous $\mathrm{NaHCO}_{3}$ was then added and the aqueous phase was extracted with $\mathrm{Et}_{2} \mathrm{O}$. The combined organic extracts were washed with brine, dried over anhydrous $\mathrm{M} \mathrm{SO}_{4}$, filtered and concentrated in vacuo. The crude mixture was then purified by flash chromatography (petroleum ether/ $/ \mathrm{Et}_{2} \mathrm{O}: 85 / 15$ ) to afford the title benzoate (22b) $(27 \mathrm{mg}$, $80 \%$ ) as a white solid.
${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 8.32-8.27(\mathrm{~m}, 2 \mathrm{H}), 8.23-8.19(\mathrm{~m}, 2 \mathrm{H}), 5.97(\mathrm{dd}, \mathrm{J}=3.2,5.0$ $\mathrm{Hz}, 1 \mathrm{H}), 5.88(\mathrm{~s}, 1 \mathrm{H}), 5.74(\mathrm{dd}, \mathrm{J}=12.1,6.9 \mathrm{~Hz}, 1 \mathrm{H}), 5.06(\mathrm{~m}, 1 \mathrm{H}), 3.04(\mathrm{dd}, \mathrm{J}=13.5,12.1 \mathrm{~Hz}$, $1 \mathrm{H}), 2.95(\mathrm{~m}, 1 \mathrm{H}), 2.13-2.06(\mathrm{~m}, 1 \mathrm{H}), 2.03(\mathrm{dd}, \mathrm{J}=13.5,6.9 \mathrm{~Hz}, 1 \mathrm{H}), 1.99-1.90(\mathrm{~m}, 1 \mathrm{H}), 1.85-$ $1.82(\mathrm{~m}, 1 \mathrm{H}), 1.81(\mathrm{~m}, 3 \mathrm{H}), 1.76-1.71(\mathrm{~m}, 1 \mathrm{H}), 1.57-1.54(\mathrm{~m}, 4 \mathrm{H}), 1.52-1.45(\mathrm{~m}, 2 \mathrm{H}), 1.30(\mathrm{~s}$, 3 H ), $1.26(\mathrm{~s}, 1 \mathrm{H}), 1.25(\mathrm{~s}, 3 \mathrm{H})$.

[^3]
## 3. X-ray Data of 22b:



The crystallographic data have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication number CCDC-976581. Copies of the data can be obtained, free of charge, via the internet (http://www.ccdc.cam.ac.uk/data_request/cif), email (data request@ccdc.cam.ac.uk), or fax: +44 1223336033.

Table 1. Crystal data and structure refinement for CCDC 976581.

| Identification code | CCDC 976581 |
| :--- | :--- |
| Empirical formula | $\mathrm{C} 26 \mathrm{H} 31 \mathrm{~N} \mathrm{O5}$ |
| Formula weight | 437.52 |
| Temperature | $150(2) \mathrm{K}$ |
| W avelength | 0.71073 A |
| Crystal system, space group | Orthorhombic, P 212121 |
| Unit cell dimensions | $\mathrm{a}=7.4950(6) \mathrm{A}$ alpha $=90 \mathrm{deg}$. |
|  | $\mathrm{b}=10.4454(9) \mathrm{A}$ beta $=90 \mathrm{deg}$. |
|  | $\mathrm{C}=35.197(3) \mathrm{A}$ gamma $=90 \mathrm{deg}$. |
| V olume | $2755.5(4) \mathrm{A} \wedge$ |


| Z, Calculated density | 4, $1.055 \mathrm{M} \mathrm{g} / \mathrm{m}^{\wedge} 3$ |
| :---: | :---: |
| A bsorption coefficient | 0.073 mm ^1 |
| F(000) | 936 |
| Crystal size | $0.370 \times 0.102 \times 0.060 \mathrm{~mm}$ |
| Theta range for data collection | 2.034 to 23.296 deg. |
| Limiting indices | $-7<=h<=8,-11<=k<=11,-33<=1<=39$ |
| R eflections collected / unique | $12353 / 3802$ [ R (int) $=0.0806$ ] |
| Completeness to theta $=25.242$ | 78.0 \% |
| A bsorption correction | Empirical |
| M ax. and min. transmission | 1.000 and 0.786 |
| Refinement method | Full-matrix least-squares on $\mathrm{F}^{\wedge} 2$ |
| D ata / restraints / parameters | 3802 / 22 / 276 |
| Goodness-of-fit on $\mathrm{F}^{\wedge} 2$ | 1.054 |
| Final R indices [ $1>2$ sigma( I ] $]$ | $R 1=0.1164, w R 2=0.2886$ |
| R indices (all data) | $R 1=0.1565, w R 2=0.3085$ |
| A bsolute structure parameter | -1.9(10) |
| Extinction coefficient | 0.103(15) |
| Largest diff. peak and hole | 0.34 and -0.31 e.A ^-3 |

Table 2. A tomic coordinates ( $\times 10^{\wedge} 4$ ) and equivalent isotropic displacement parameters ( $\mathrm{A}^{\wedge} 2 \times 10^{\wedge} 3$ ) for CCDC 976581
$U(e q)$ is defined as one third of the trace of the orthogonalized Uij tensor.

|  | X | y | Z | $\mathrm{U}(\mathrm{eq})$ |
| :---: | :---: | :---: | :---: | :---: |
| C(1) | 5477(13) | 4164(10) | 1175(3) | 33(3) |
| C(2) | 7380(13) | 4134(15) | 1016(3) | 50(3) |
| C(3) | 7450(20) | 4009(15) | 578(3) | 70(4) |
| C(4) | 6006(17) | 3919(17) | 349(4) | 71(5) |
| C(5) | 6240(20) | 3798(18) | -73(4) | 94(6) |


| C(6) | 4263(15) | 4162(15) | 536(3) | 55(4) |
| :---: | :---: | :---: | :---: | :---: |
| C(7) | 4141(14) | 3430(10) | 924(3) | 42(3) |
| C(8) | 4730(20) | 2005(13) | 883(5) | 84(5) |
| C(9) | 2260(14) | 3401(16) | 1102(3) | 67(4) |
| C(10) | 3301(15) | 5041(13) | 390(3) | 48(3) |
| C(11) | 1935(16) | 5852(13) | 610(4) | 65(4) |
| $\mathrm{C}(12)$ | 2800(30) | 6945(17) | 866(6) | 52(6) |
| C(13) | 1450(40) | 7260(30) | 1169(7) | 85(9) |
| C(14) | 2850(40) | 8190(30) | 642(11) | 141(14 |
| C(12') | 3050(30) | 7010(20) | 707(8) | 24(8) |
| $\mathrm{C}\left(13^{\prime}\right)$ | 2150(50) | 7740(30) | 1025(9) | 51(11) |
| $\mathrm{C}\left(14^{\prime}\right)$ | 3520(40) | 7860(30) | 373(8) | 41(10) |
| $\mathrm{C}\left(15^{\prime}\right)$ | 5020(40) | 8850(30) | 441(13) | 71(15) |
| $\mathrm{C}\left(16^{\prime}\right)$ | 6680(40) | 8030(30) | 496(10) | 41(9) |
| C(17) | 6270(40) | 6920(30) | 754(10) | 46(11) |
| C(15) | 4440(30) | 8440(30) | 402(7) | 78(8) |
| C(16) | 6190(40) | 8370(30) | 628(8) | 82(9) |
| C (17) | 6240(20) | 7242(18) | 892(6) | 37(6) |
| C(18) | 4758(15) | 6545(12) | 953(4) | 65(4) |
| $\mathrm{C}(19)$ | 4833(15) | 5523(9) | 1264(3) | 37(3) |
| C(20) | 5352(17) | 6508(13) | 1862(4) | 55(3) |
| C(21) | 6739(15) | 7043(12) | 2120(4) | 51(3) |
| C(22) | 6244(17) | 7700(17) | 2459(4) | 84(6) |
| C(23) | 7474(17) | 8236(18) | 2705(3) | 78(5) |
| C(24) | 9280(14) | 8029(13) | 2611(3) | 45(3) |


| $\mathrm{C}(25)$ | $9797(15)$ | $7377(12)$ | $2305(3)$ | $45(3)$ |
| :--- | :--- | :--- | :--- | :--- |
| $\mathrm{C}(26)$ | $8536(14)$ | $6912(13)$ | $2060(4)$ | $53(4)$ |
| $\mathrm{N}(1)$ | $10511(14)$ | $8601(11)$ | $2889(3)$ | $56(3)$ |
| $\mathrm{O}(1)$ | $5418(10)$ | $3552(10)$ | $1536(2)$ | $62(3)$ |
| $\mathrm{O}(2)$ | $6059(9)$ | $6029(8)$ | $1558(2)$ | $45(2)$ |
| O(3) | $3806(11)$ | $6566(9)$ | $1942(2)$ | $68(3)$ |
| O(4) | $10033(11)$ | $9104(10)$ | $3177(2)$ | $65(3)$ |
| O(5) | $12132(11)$ | $8489(12)$ | $2802(3)$ | $89(4)$ |

Table 3. B ond lengths [A ] and angles [deg] for CCDC 976581.
$\mathrm{C}(1)-\mathrm{O}(1) \quad 1.423(12)$
$\mathrm{C}(1)-\mathrm{C}(19) \quad 1.531(14)$
$C(1)-C(2) \quad 1.532(14)$
$\mathrm{C}(1)-\mathrm{C}(7) \quad 1.538(15)$
$\mathrm{C}(2)-\mathrm{C}(3) \quad 1.550(15)$
$C(3)-C(4) \quad 1.352(19)$
$C(4)-C(6) \quad 1.485(17)$
$C(4)-C(5) \quad 1.500(17)$
$C(6)-C(10) \quad 1.275(16)$
$C(6)-C(7) \quad 1.570(15)$
$C(7)-C(9) \quad 1.542(15)$
$\mathrm{C}(7)-\mathrm{C}(8) \quad 1.559(17)$
$C(10)-C(11) \quad 1.539(16)$
$C(11)-C(12) \quad 1.594(19)$
$C(12)-C(13) \quad 1.51(2)$

| C(12)-C(14) | 1.53(2) |
| :---: | :---: |
| $\mathrm{C}(12)-\mathrm{C}(18)$ | 1.55(2) |
| C(14)-C(15) | 1.48(2) |
| $\mathrm{C}\left(12^{\prime}\right)-\mathrm{C}\left(13^{\prime}\right)$ | 1.52(2) |
| C(12')-C(14') | 1.52(2) |
| C(12')-C(18) | 1.62(3) |
| $\mathrm{C}\left(14^{\prime}\right)-\mathrm{C}\left(15^{\prime}\right)$ | 1.54(3) |
| $\mathrm{C}\left(15^{\prime}\right)-\mathrm{C}\left(16^{\prime}\right)$ | 1.52(2) |
| C(16')-C(17') | 1.50(2) |
| $C\left(17^{\prime}\right)-\mathrm{C}(18)$ | 1.39(2) |
| $\mathrm{C}(15)-\mathrm{C}(16)$ | 1.53(2) |
| C(16)-C(17) | 1.50(2) |
| $\mathrm{C}(17)-\mathrm{C}(18)$ | 1.344(17) |
| $\mathrm{C}(18)-\mathrm{C}(19)$ | 1.531(15) |
| $\mathrm{C}(19)-\mathrm{O}(2)$ | 1.483(12) |
| $\mathrm{C}(20)-\mathrm{O}(3)$ | 1.194(13) |
| $\mathrm{C}(20)-\mathrm{O}(2)$ | 1.293(14) |
| C(20)-C(21) | 1.489(17) |
| C(21)-C(26) | 1.370(15) |
| C(21)-C(22) | 1.427(16) |
| C(22)-C(23) | 1.384(17) |
| C(23)-C(24) | 1.410(16) |
| C(24)-C(25) | 1.333(15) |
| $\mathrm{C}(24)-\mathrm{N}(1)$ | 1.471(15) |
| C(25)-C(26) | 1.367(16) |


| $\mathrm{N}(1)-\mathrm{O}(4)$ | 1.197(12) |
| :---: | :---: |
| $\mathrm{N}(1)-\mathrm{O}(5)$ | 1.258(13) |
| $\mathrm{O}(1)-\mathrm{C}(1)-\mathrm{C}(19)$ | 103.0(8) |
| $\mathrm{O}(1)-\mathrm{C}(1)-\mathrm{C}(2)$ | 110.2(8) |
| $\mathrm{C}(19)-\mathrm{C}(1)-\mathrm{C}(2)$ | 112.8(10) |
| $\mathrm{O}(1)-\mathrm{C}(1)-\mathrm{C}(7)$ | 105.5(8) |
| $\mathrm{C}(19)-\mathrm{C}(1)-\mathrm{C}(7)$ | 112.0(8) |
| $\mathrm{C}(2)-\mathrm{C}(1)-\mathrm{C}(7)$ | 112.7(9) |
| $C(1)-C(2)-C(3)$ | 113.3(9) |
| $C(4)-C(3)-C(2)$ | 124.9(12) |
| $\mathrm{C}(3)-\mathrm{C}(4)-\mathrm{C}(6)$ | 115.4(11) |
| $C(3)-C(4)-C(5)$ | 120.0(12) |
| $C(6)-C(4)-C(5)$ | 123.8(12) |
| $C(10)-C(6)-C(4)$ | 116.3(11) |
| $\mathrm{C}(10)-\mathrm{C}(6)-\mathrm{C}(7)$ | 132.0(11) |
| $\mathrm{C}(4)-\mathrm{C}(6)-\mathrm{C}(7)$ | 110.7(11) |
| $\mathrm{C}(1)-\mathrm{C}(7)-\mathrm{C}(9)$ | 111.9(9) |
| $C(1)-C(7)-C(8)$ | 110.2(9) |
| $C(9)-C(7)-C(8)$ | 106.0(11) |
| $\mathrm{C}(1)-\mathrm{C}(7)-\mathrm{C}(6)$ | 102.6(8) |
| $\mathrm{C}(9)-\mathrm{C}(7)-\mathrm{C}(6)$ | 114.5(9) |
| $C(8)-C(7)-C(6)$ | 111.6(11) |
| $\mathrm{C}(6)-\mathrm{C}(10)-\mathrm{C}(11)$ | 124.7(11) |
| $\mathrm{C}(10)-\mathrm{C}(11)-\mathrm{C}(12)$ | 114.0(12) |


| $C(13)-C(12)-C(14)$ | 101(2) |
| :---: | :---: |
| $C(13)-C(12)-C(18)$ | 123.6(18) |
| $\mathrm{C}(14)-\mathrm{C}(12)-\mathrm{C}(18)$ | 108.0(19) |
| $\mathrm{C}(13)-\mathrm{C}(12)-\mathrm{C}(11)$ | 106.3(16) |
| $\mathrm{C}(14)-\mathrm{C}(12)-\mathrm{C}(11)$ | 109(2) |
| $\mathrm{C}(18)-\mathrm{C}(12)-\mathrm{C}(11)$ | 107.6(13) |
| $\mathrm{C}(15)-\mathrm{C}(14)-\mathrm{C}(12)$ | 118(3) |
| $C\left(13^{\prime}\right)-C\left(12^{\prime}\right)-C\left(14^{\prime}\right)$ | 112(2) |
| $C\left(13^{\prime}\right)-C\left(12^{\prime}\right)-C(18)$ | 96(2) |
| $C\left(14^{\prime}\right)-C\left(12^{\prime}\right)-C(18)$ | 113.9(19) |
| $\mathrm{C}\left(12^{\prime}\right)-\mathrm{C}\left(14^{\prime}\right)-\mathrm{C}\left(15^{\prime}\right)$ | 116(2) |
| $C\left(16^{\prime}\right)-C\left(15^{\prime}\right)-C\left(14^{\prime}\right)$ | 104(3) |
| C(17) $-\mathrm{C}\left(16^{\prime}\right)-\mathrm{C}\left(15^{\prime}\right)$ | 110(3) |
| $C(18)-C\left(17^{\prime}\right)-C\left(16^{\prime}\right)$ | 134(3) |
| $\mathrm{C}(14)-\mathrm{C}(15)-\mathrm{C}(16)$ | 113(2) |
| $\mathrm{C}(17)-\mathrm{C}(16)-\mathrm{C}(15)$ | 112(2) |
| $C(18)-C(17)-C(16)$ | 120.4(18) |
| $\mathrm{C}(17)-\mathrm{C}(18)-\mathrm{C}(19)$ | 117.5(12) |
| $\mathrm{C}\left(17^{\prime}\right)-\mathrm{C}(18)-\mathrm{C}(19)$ | 121.9(16) |
| $C(17)-C(18)-C(12)$ | 126.9(14) |
| $C(19)-C(18)-C(12)$ | 111.2(12) |
| $C\left(17^{\prime}\right)-C(18)-C\left(12^{\prime}\right)$ | 107.0(18) |
| $C(19)-C(18)-C\left(12^{\prime}\right)$ | 128.3(12) |
| $\mathrm{O}(2)-\mathrm{C}(19)-\mathrm{C}(1)$ | 106.2(8) |
| $\mathrm{O}(2)-\mathrm{C}(19)-\mathrm{C}(18)$ | 105.9(8) |


| $\mathrm{C}(1)-\mathrm{C}(19)-\mathrm{C}(18)$ | $120.8(9)$ |
| :--- | :--- |
| $\mathrm{O}(3)-\mathrm{C}(20)-\mathrm{O}(2)$ | $127.7(11)$ |
| $\mathrm{O}(3)-\mathrm{C}(20)-\mathrm{C}(21)$ | $121.0(11)$ |
| $\mathrm{O}(2)-\mathrm{C}(20)-\mathrm{C}(21)$ | $111.3(10)$ |
| $\mathrm{C}(26)-\mathrm{C}(21)-\mathrm{C}(22)$ | $115.6(12)$ |
| $\mathrm{C}(26)-\mathrm{C}(21)-\mathrm{C}(20)$ | $123.7(12)$ |
| $\mathrm{C}(22)-\mathrm{C}(21)-\mathrm{C}(20)$ | $120.6(10)$ |
| $\mathrm{C}(23)-\mathrm{C}(22)-\mathrm{C}(21)$ | $123.0(12)$ |
| $\mathrm{C}(22)-\mathrm{C}(23)-\mathrm{C}(24)$ | $115.5(12)$ |
| $\mathrm{C}(25)-\mathrm{C}(24)-\mathrm{C}(23)$ | $123.2(12)$ |
| $\mathrm{C}(25)-\mathrm{C}(24)-\mathrm{N}(1)$ | $124.3(10)$ |
| $\mathrm{C}(23)-\mathrm{C}(24)-\mathrm{N}(1)$ | $112.5(11)$ |
| $\mathrm{C}(24)-\mathrm{C}(25)-\mathrm{C}(26)$ | $119.3(10)$ |
| $\mathrm{C}(25)-\mathrm{C}(26)-\mathrm{C}(21)$ | $123.2(12)$ |
| $\mathrm{O}(4)-\mathrm{N}(1)-\mathrm{O}(5)$ | $122.4(10)$ |
| $\mathrm{O}(4)-\mathrm{N}(1)-\mathrm{C}(24)$ | $123.6(10)$ |
| $\mathrm{O}(5)-\mathrm{N}(1)-\mathrm{C}(24)$ | $114.0(11)$ |
| $\mathrm{C}(20)-\mathrm{O}(2)-\mathrm{C}(19)$ | $117.5(8)$ |

Symmetry transformations used to generate equival ent atoms:
Table 4. A nisotropic displacement parameters (A ^2 $\times 10^{\wedge} 3$ ) for CCDC 976581
The anisotropic displacement factor exponent takes the form:
-2 pi^2 [ h^2 a*^2 U11 + ... +2 hk a* b* U 12 ]

|  | U 11 | U 22 | U33 | U 23 | U 13 | U 12 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| C(2) | 21(6) | 111(11) | 18(6) | -5(6) | -1(5) | 13(7) |

```
C(3) 66(10) 107(12) 39(7) -9(8) 14(8) 39(9)
C(4) 38(8) 131(14) 44(8) -6(8) 10(7) 30(8)
C(5) 124(14) 118(14) 40(8) -12(9) 4(9) 21(12)
C(6) 21(6) 106(10) 37(7) -3(7) -2(5) -15(7)
C(8) 92(11) 52(9) 107(13) -16(8) -33(10) 6(8)
C(9) 22(6)
C(10) 28(7) 77(9) 38(7) 9(7) -3(6) 14(7)
C(11) 49(8) 82(10) 64(9)
C(18) 46(8) 59(9) 89(10) -16(8) -22(8) 13(7)
C(20) 38(8) 76(9) 53(8) -18(7) 1(7) 10(7)
C(21) 26(7) 54(8) 72(9) -12(7) 6(6) 4(6)
C(22) 29(7) 157(16) 66(10)
C(23) 47(8) 160(16) 28(7)
C(24) 24(6) 78(8) 34(7) 2(6) -7(5) 15(6)
C(25) 24(6) 86(9) 25(6) 3(6) -3(6) 1(6)
C(26) 24(7) 72(9) 63(9) -18(7) 5(6) 19(6)
N(1) 45(7) 75(8) 48(7) 4(6) -7(6) -4(6)
O(1) 35(5) 113(7) 39(5) 27(5) 1(4) -30(5)
O(2) 33(4) 60(5) 43(5) -20(4) 0(4) 11(4)
O(3) 32(5) 102(7) 70(6) -44(6) 13(5) 1(5)
O(4) 62(6) 102(7) 30(5)
O(5) 26(5) 162(11) 80(7) -49(7) -16(5) 21(6)
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## 4. NMR Spectra of New Compounds



 $\begin{array}{lllllll}8.5 & 8.0 & 7.5 & 7.0 & 6.5 & 6.0 & 5.0\end{array}$

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 $\underbrace{\text { Nu }}$



[^0]:    ${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 5.80(\mathrm{t}, \mathrm{J}=4.0 \mathrm{~Hz}, 1 \mathrm{H}), 5.49(\mathrm{dtd}, \mathrm{J}=7.9,6.7,1.3 \mathrm{~Hz}, 1 \mathrm{H})$, $5.38(\mathrm{~m}, 1 \mathrm{H}), 5.22(\mathrm{~s}, 1 \mathrm{H}), 3.64(\mathrm{~m}, 2 \mathrm{H}), 2.75(\mathrm{~m}, 1 \mathrm{H}), 2.65(\mathrm{~m}, 1 \mathrm{H}), 2.10(\mathrm{dd}, \mathrm{J}=9.7,5.3 \mathrm{~Hz}$, $2 \mathrm{H}), 1.76(\mathrm{~s}, 3 \mathrm{H}), 1.65(\mathrm{dd}, \mathrm{J}=6.2,1.2 \mathrm{~Hz}, 3 \mathrm{H}), 1.36-1.70(\mathrm{~m}, 8 \mathrm{H}), 1.32(\mathrm{~s}, 3 \mathrm{H}), 1.29(\mathrm{~s}, 3 \mathrm{H})$, 1.08 (s, 3H).
    ${ }^{13}$ C NMR (126 M Hz, CDCl 3 ) $\delta$ ppm: 155.4, 139.0, 132.9, 127.7, 125.9, 89.4, 83.0, 79.8, 79.7, $63.3,41.7,36.9,36.2,35.5,35.2,26.0,25.8,24.8,24.8,24.6,18.6,18.2,3.7$.

    IR ( $1 / 2 \mathrm{~cm}^{-1}$ ): 3620, 2958, 2931, 1807, 1558, 1463, 1380, 1263, 1188, 1117.
    HRMS (EI) Calcd. for [ $\mathrm{C}_{23} \mathrm{H}_{34} \mathrm{O}_{4}$ ]: 374.2457, found: 374.2461.

[^1]:    ${ }^{1} \mathbf{H} \operatorname{NMR}\left(500 \mathrm{M} \mathrm{Hz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 6.10(\mathrm{t}, \mathrm{J}=4.1 \mathrm{~Hz}, 1 \mathrm{H}), 5.51(\mathrm{~m}, 1 \mathrm{H}), 5.40(\mathrm{~m}, 1 \mathrm{H}), 5.29(\mathrm{~s}$, $1 \mathrm{H}), 3.62(\mathrm{dt}, \mathrm{J}=6.6,1.9 \mathrm{~Hz}, 2 \mathrm{H}), 2.75(\mathrm{ddt}, \mathrm{J}=15.6,6.4,1.3 \mathrm{~Hz}, 1 \mathrm{H}), 2.61(\mathrm{dd}, \mathrm{J}=15.6,7.0$

[^2]:    ${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right) \delta \mathrm{ppm}: 8.07(\mathrm{~d}, \mathrm{~J}=7.4 \mathrm{~Hz}, 2 \mathrm{H}), 7.54(\mathrm{t}, \mathrm{J}=7.4 \mathrm{~Hz}, 1 \mathrm{H}), 7.44(\mathrm{t}, \mathrm{J}=$ $7.6 \mathrm{~Hz}, 2 \mathrm{H}), 6.49(\mathrm{t}, \mathrm{J}=3.9 \mathrm{~Hz}, 2 \mathrm{H}), 5.97(\mathrm{~s}, 1 \mathrm{H}), 5.78-5.89(\mathrm{~m}, 1 \mathrm{H}), 5.60-5.68(\mathrm{~m}, 1 \mathrm{H}), 5.40$ $(\mathrm{dq}, \mathrm{J}=12.9,6.3 \mathrm{~Hz}, 1 \mathrm{H}), 5.05(\mathrm{~m}, 2 \mathrm{H}), 2.85(\mathrm{~s}, 1 \mathrm{H}), 2.50(\mathrm{t}, \mathrm{J}=8.2 \mathrm{~Hz}, 2 \mathrm{H}), 2.42(\mathrm{dd}, \mathrm{J}=13.2$, $6.8 \mathrm{~Hz}, 1 \mathrm{H}), 2.19(\mathrm{dd}, \mathrm{J}=13.2,7.7 \mathrm{~Hz}, 1 \mathrm{H}), 2.11(\mathrm{~m}, 2 \mathrm{H}), 1.70(\mathrm{~d}, \mathrm{~J}=6.3 \mathrm{~Hz}, 3 \mathrm{H}), 1.52-1.62$ $(\mathrm{m}, 4 \mathrm{H}), 1.36(\mathrm{~s}, 3 \mathrm{H}), 1.31(\mathrm{~s}, 3 \mathrm{H}), 1.29(\mathrm{~s}, 3 \mathrm{H}), 1.07(\mathrm{~s}, 3 \mathrm{H})$.

[^3]:    ${ }^{13} \mathbf{C}$ NMR ( $126 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ) $\delta \mathrm{ppm}$ : 163.9, 150.5, 148.5, 141.4, 136.9, 136.3, 130.7, 128.1, $125.3,123.6,117.7,81.0,76.5,43.2,42.4,40.6,40.3,33.6,27.2,26.1,25.8,22.8,19.2,18.6$.

