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Kinetic resolution of 4,5-dihydroxylated cyclopentenones

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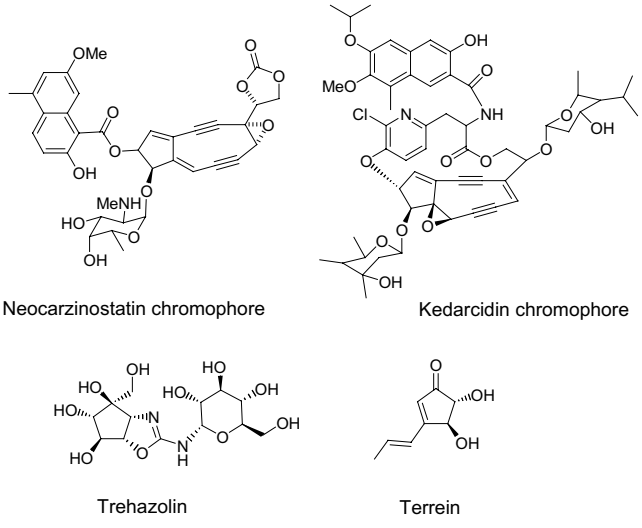
Abstract—An asymmetric synthesis of *trans*-4,5-dihydroxylated cyclopentenones has been developed. The method involves a lipase-mediated kinetic resolution.

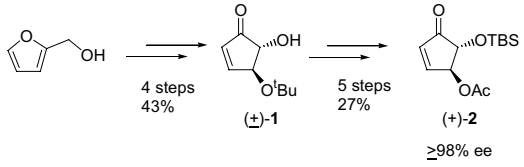
1. Introduction

The polyhydroxylated cyclopentane unit is present in a number of natural products, such as Neocarzinostatin chromophore, Kedarcidin chromophore, Trehazolin and Terrein (Scheme 1).[1]

Dihydroxylated cyclopentenones are versatile precursors for the preparation of such natural products. Although a number of routes to *cis*-dihydroxylated cyclopentenones have been published,[2] fewer syntheses of the *trans*-adducts have been reported.[3–6] Within our laboratory, we have devised a convenient synthesis of racemic dihydroxylated cyclopentenone **1** from furfuryl alcohol, attainable in quantities of up to 50 g, for use in our studies towards the synthesis of Neocarzinostatin chromophore.[7] We have further manipulated **1** in order to synthesise the enantiomer required in our synthesis, **2**, by use of some work by Hirama[3] involving an enzymatic desymmetrisation (Scheme 2).[8]



Scheme 1.



Scheme 2.

2. Results and discussion

The longevity of the desymmetrisation pathway motivated us to seek other alternatives for the production of an enantiomerically pure dihydroxylated cyclopentenone. (±)-**3** was subjected to kinetic resolution conditions using Lipase (Amano AK), which had previously been used successfully for the desymmetrisation pathway. The resolution resulted in the desired enantiomer, (+)-**3** as the unreacted alcohol in 39% and ⩾98% ee and the undesired enantiomer (−)-**2** as the acetate in 38% and ⩾98% ee (Scheme 3).[9]

Enantiomeric excesses were determined throughout by comparison to known compounds[3] and by the two-step

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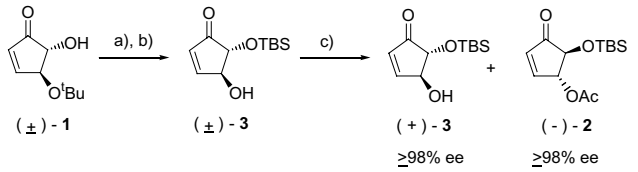
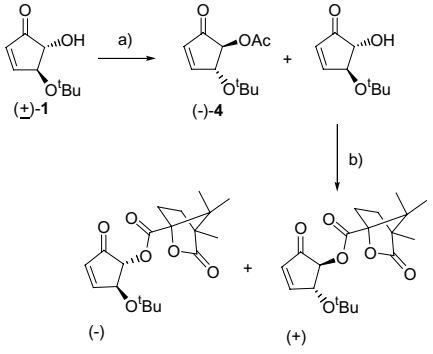


Scheme 3. Reagents and conditions: (a) TBS-Cl, DCM, Im, 0 °C, 90%; (b) $TiCl_4$, DCM, −78 °C, 73%; (c) lipase (Amano AK), vinyl acetate, 38% of **2**, 39% of **3**.

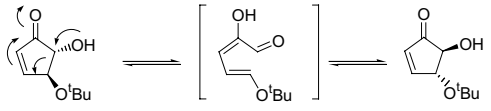
sequence of Luche reduction[9] of the ketone followed by derivatisation of the resultant alcohol with 1*S*-(−)-camphanic chloride.

We sought to shorten further this route by resolving compound (±)-**1**. After screening several lipases, we found we were effectively able to synthesise acetate (−)-**4** in 50% yield and ⩾95% ee. However, it appeared that unreacted **1** was a racemic mixture; derivatising it with 1*S*-(−)-camphanic chloride resulted in an approximate 1:1 mixture of diastereomers (Scheme 4).



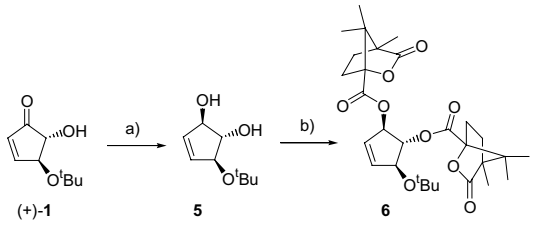
Scheme 4. Reagents and conditions: (a) Lipase (Amano PS), vinyl acetate, 36 °C, 50% of (−)-**4**, 45% of **1**; (b) 1*S*-(−)-camphanic chloride, Et_3N, DMAP, DCM.

We suspected that the conditions used to derivatise the alcohol were inducing racemisation. This was noteworthy because the mechanism would necessarily require the loss of stereochemistry at both the 4- and 5-positions. One possible explanation would be that the ring contraction used for the synthesis of **1** might be reversible (Scheme 5).



Scheme 5.

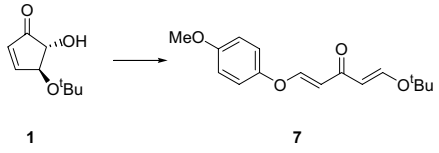
In order to ascertain whether this was indeed the case, we needed to determine whether unreacted **1** was present in good enantiomeric purity at the completion of the kinetic resolution. By first reducing the ketone, ring opening of **1** should no longer be possible, and hence we should then be able to determine the ee by derivatisation with 1*S*-(−)-camphanic chloride. Thus unreacted **1** was subjected to Luche reduction conditions[9] to give diol **5**, which was then treated with 1*S*-(−)-camphanic chloride. Only one diastereomer of the resulting compound **6** was observed, leading us to conclude that **1** was being produced in ⩾95% ee from the kinetic resolution, and that under basic conditions, racemisation was occurring (Scheme 6).



Scheme 6. Reagents and conditions: (a) $CeCl_3{\cdot}7H_2O$, $NaBH_4$, MeOH, 0 °C, 48% **5** as major diastereomer, 17% minor diastereomer; (b) 1*S*-(−)-camphanic chloride, Et_3N, DMAP, DCM, 90%.

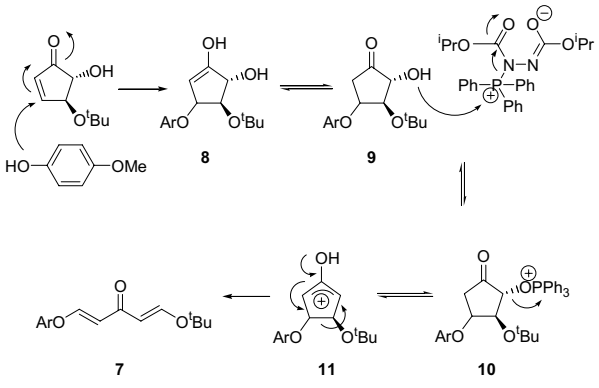
Further confirmation of this result was attained by stirring (+)-**1** in the presence of triethylamine; after 3 h the optical rotation had been reduced to 0, indicating racemisation. (+)-**1** was also found to slowly racemise upon standing.

During the course of our studies, we have also sought to synthesise *cis*-dihydroxylated cyclopentenones from our *trans*-derivatives. Although this has not been possible, we did uncover an example of what would appear to be a retro-Nazarov reaction, as has been reported by Harmata (Scheme 7).[10]



Scheme 7. Reagents and conditions: THF, PPh_3, 4-methoxyphenol, 0 °C then DIAD, rt, 14%.

We propose one possible explanation for this is as follows. Conjugate addition of 4-methoxyphenol, followed by loss of triphenylphosphine oxide results in cation **11**. This species then undergoes the retro-Nazarov process to result in ring-opened compound **7** (Scheme 8).



Scheme 8.

In conclusion, we have simplified the asymmetric synthesis of dihydroxylated cyclopentenones required for our synthetic work towards Neocarzinostatin chromophore, and uncovered some interesting side reactions of compounds of this type.

3. Experimental

All glassware was oven or flame dried prior to use. All reagents and solvents were purchased from commercial sources and used as supplied or purified using standard methods. Preparations were carried out under an inert atmosphere unless otherwise stated. ^{1}H NMR spectra were recorded on a Bruker spectrometer at 300 MHz operating at ambient probe temperature. Coupling constants were measured in hertz (Hz). ^{13}C NMR spectra were recorded at 75 MHz in $CDCl_3$ using residual $CHCl_3$ as internal reference. Infrared spectra were recorded on a Perkin–Elmer 1710 FTIR spectrometer as thin films or solutions. Mass spectra were recorded on a MS25 spectrometer. Analytical thin layer chromatography was carried out using SIL G/UV$_{254}$ plates and visualised using standard procedures. Melting points are uncorrected.

3.1. (4*S*,5*R*)-4-Hydroxy-5-^{t}butyldimethylsilyoxy-cyclopenten-1-one (+)-3 and (4*R*,5*S*)-4-acetoxy-5-^{t}butyldimethylsilyoxy-cyclopenten-1-one (−)-2

To (±)-**3** (2.41 g, 10.57 mmol) stirring in benzene (10 mL) was added Lipase AK followed by vinyl acetate (20 mL). The reaction mixture was stirred at 34 °C for 10 h then filtered and concentrated in vacuo. Column chromatography eluting with 20–70% EtOAc/PE resulted in (+)-**3** as a white solid, mp 61–62 °C, (0.951 g, 39%) and (−)-**2** as a colourless oil (1.087 g, 38%). (−)-**2** R_f (20% EtOAc/PE) 0.59. $[\alpha]_D^{30} = -143.4$ (*c* 1.02, $CHCl_3$). ν_{max} (cm^{-1}) 2930, 2858, 1742 (C=O), 1473, 1370. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.23 (1H, dd, $J = 6.2, 1.7$), 6.17 (1H, d, $J = 6.2$), 5.56–5.52 (1H, m), 4.15 (1H, d, $J = 2.6$), 2.01 (3H, s), 0.79 (9H, s), 0.04 (3H, s), 0.00 (3H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 203.2, 171.9, 157.0, 135.8, 80.5, 79.8, 27.3, 22.5, 18.1, −3.00, −3.60. *m*/*z* (EI) 271 (M+H). HRMS (ES) calculated for $C_{13}H_{23}O_4Si$ (M+H) 271.1365. Found 271.1371. (+)-**3** R_f (20% EtOAc/PE) 0.24. $[\alpha]_D^{25} = +91.8$ (*c* 1.14, $CHCl_3$). ν_{max} (cm^{-1}) 2985, 1741 (C=O). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.18 (1H, dd, $J = 6.4, 1.5$), 6.04 (1H, d, $J = 6.4$), 4.60–4.56 (1H, m), 3.99–3.93 (1H, m), 2.16–2.14 (1H, m), 0.78 (9H, s), 0.04 (3H), 0.0 (3H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 203.2, 158.8, 133.1, 82.7, 78.1, 26.2, 18.8, −4.1, −4.7. *m*/*z* (EI) 213 (M−CH_3). HRMS (ES) calculated for $C_{11}H_{21}O_3Si$ (M+H) 229.1260. Found 229.1262.

Determination of ee of (+)-**3**:

3.1.1. (4*S*,5*R*)-4-acetoxy-5-^{t}butyldimethylsilyoxy-cyclopenten-1-one (+)-2.

To (+)-**3** (0.136 g, 0.6 mmol) and DMAP (0.007 g, 0.06 mmol) stirring in triethylamine (3 mL) at 0 °C was added acetic anhydride (0.062 mL, 0.66 mmol) dropwise. The reaction mixture was stirred at 0 °C for 1 h, allowed to warm to room temperature over 1 h 30 min then quenched with HCl (3 mL, 1 M aqueous solution). The organics were extracted with ethyl acetate (3×5 mL), washed with sodium bicarbonate (5 mL, saturated solution), dried over magnesium sulfate, filtered and concentrated in vacuo. Column chromatography eluting with 20% EtOAc/PE resulted in a colourless oil (0.13 g, 80%). $[\alpha]_D^{30} = +145.4$ (*c* 1.02, $CHCl_3$). The spectral details are in exact accordance with those given for (−)-**2**.

3.1.2. (3*S*,4*R*,5*R*)-3-Acetoxy-4-^{t}butyldimethysilyloxy-5-hydroxy-cyclopent-2-ene 3a.

To (+)-**2** (0.245 g, 0.91 mmol) and $CeCl_3{\cdot}7H_2O$ (0.45 g, 1.22 mmol) stirring in methanol (4 mL) at 0 °C was added $NaBH_4$ (0.05 g, 1.42 mmol) portionwise over 10 min. The reaction mixture was stirred at 0 °C for 1 h 30 min then quenched with ammonium chloride (5 mL, saturated solution), extracted with ethyl acetate (5×4 mL), washed with brine (10 mL), dried over magnesium sulfate, filtered and concentrated in vacuo. Column chromatography eluting with 20% EtOAc/PE resulted in a colourless oil (0.196 g, 79%). R_f (10% EtOAc/PE) 0.13. $[\alpha]_D^{30} = +61.5$ (*c* 1.00, $CHCl_3$). ν_{max} (cm^{-1}) 3415 (OH), 2360, 1641 (C=O), 1025. ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.83 (1H, d, $J = 6.0$), 5.72 (1H, d, $J = 6.0$), 5.21–5.24 (1H, m), 4.38–4.40 (1H, m), 4.04 (1H, t, $J = 3.8$), 1.98 (3H, s), 1.75 (1H, d, $J = 7.2$), 0.81 (9H, s), 0.03 (3H, s), 0.00 (3H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.4, 134.3, 129.3, 84.8, 81.6, 79.5, 24.4, 19.7, 16.7, −4.6. *m*/*z* (FAB) 295 (M+Na). HRMS (ES) calculated for $C_{13}H_{25}O_4Si$ (M+H) 273.1522. Found 273.1526.

3.1.3. (3*S*,4*R*,5*R*)-3-Acetoxy-4-^{t}butyldimethylsilyloxy-5-camphanoxycyclopent-2-ene 3b.

To **3a** (0.32 g, 1.19 mmol) stirring in DCM (5 mL) at 0 °C was added 1*S*(−)-camphanic chloride (0.31 g, 1.43 mmol), DMAP (0.029 g, 0.24 mmol) and triethylamine (0.198 mL, 1.43 mmol). The reaction mixture was stirred for 30 min then quenched with ammonium chloride (5 mL, saturated solution), extracted with ether (3×5 mL), washed with brine (10 mL), dried over magnesium sulfate, filtered and concentrated in vacuo. Column chromatography eluting with 10–20% Et_2O/PE resulted in a white solid, mp 74–75 °C (0.34 g, 63%). Anal. Calcd for $C_{23}H_{36}O_7Si$: C, 61.03; H, 8.02. Found C, 61.14; H, 8.16. R_f (20% EtOAc/PE) 0.54. $[\alpha]_D^{18} = -28.9$ (*c* 1.4, $CHCl_3$). ν_{max} (cm^{-1}) 2959, 2932, 2858, 1790 (C=O), 1739 (C=O), 1472, 1397. ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.91 (1H, d, $J = 6.0$), 5.86 (1H, d, $J = 6.0$), 5.44–5.41 (1H, m), 5.34–5.29 (1H, m), 4.35–4.31 (1H, m), 2.40–2.31 (1H, m), 2.01 (3H, s), 1.97–1.81 (2H, m), 1.67–1.58 (1H, m), 1.04 (3H, s), 0.99 (3H, s), 0.90 (3H, s), 0.79 (9H, s), 0.00 (6H, s). ^{13}C NMR (300 MHz, $CDCl_3$) δ 178.3, 170.8, 167.5, 133.9, 132.0, 91.2, 84.4, 82.9, 82.5, 55.2, 54.6, 31.1, 29.4, 26.0, 21.3, 18.3, 17.3, 17.2, 10.1, −4.4, −4.5. *m*/*z* (EI) 395 (M−C_4H_9). HRMS (ES) calculated for $C_{23}H_{40}O_7SiN$ (M+NH_4) 470.2569. Found 470.2572.

3.2. (4*S*,5*R*)-4-^{t}Butoxy-5-hydroxy-cyclopenten-1-one (+)-1 and (4*R*,5*S*)-4-^{t}butoxy-5-acetoxy-cyclopenten-1-one (−)-4

To (±)-**1** (0.128 g, 0.75 mmol) and Lipase PS (0.5 g) was added vinyl acetate (6 mL). The reaction mixture was stirred at 40 °C for 7 days then filtered and concentrated in vacuo. Column chromatography eluting with 10–20% EtOAc/PE resulted in (−)-**4** as a yellow solid, mp 48–50 °C (0.082 g, 50%) and (+)-**1** as an off-white solid, mp 61–63 °C (0.058 g, 45%). (−)-**4** R_f (20% EtOAc/PE) 0.30. $[\alpha]_D^{28} = -142.3$ (*c* 1.0, $CHCl_3$). ν_{max} (cm^{-1}) 3055, 2982, 1727 (C=O), 1630 (C=C). ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.26 (1H, dd, $J = 6.2, 2.1$), 6.21 (1H, dd, $J = 6.2, 1.5$), 4.96 (1H, d, $J = 2.8$), 4.75–4.80 (1H, m), 2.10 (3H, s), 1.19 (9H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 199.4, 170.4, 160.7, 133.0, 81.3, 75.6, 74.1, 28.5, 20.9. *m/z* (EI) 212 (M+). HRMS (ES) calculated for $C_{11}H_{20}O_4N$ (M+NH_4) 230.1392. Found 230.1391. (+)-**1** $[\alpha]_D^{28} = +25.7$ (*c* 1.0 $CHCl_3$). ν_{max} (cm^{-1}) 3430 (OH), 2979, 1719 (C=O). 1615 (C=C), 1393. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.29 (1H, dd, $J = 6.0, 1.8$), 6.17 (1H, d, $J = 6.0$), 4.51–4.55 (1H, m), 4.01 (1H, d, $J = 2.2$), 2.81 (1H, br s), 1.25 (9H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 205.0, 161.5, 131.3, 80.7, 76.4, 75.1, 28.2. *m/z* (EI) 171 (M+H). HRMS (EI) calculated for $C_8H_{11}O_3$ (M−CH_3) 155.0708. Found 155.0703.

Determination of ee of (−)-**4**:

3.2.1. (3*R*,4*S*,5*S*)-3-^{t}Butoxy-4-acetoxy-5-hydroxycyclopent-2-ene 4a.

To (−)-**4** (0.538 g, 2.54 mmol) stirring in methanol (4 mL) at 0 °C was added $CeCl_3{\cdot}7H_2O$ (1.23 g, 3.3 mmol) followed by sodium borohydride (0.144 g, 3.81 mmol) portionwise over 20 min. The mixture was stirred for a further 30 min then quenched with ammonium chloride (3 mL, saturated solution), extracted with ethyl acetate (3×5 mL), washed with brine (5 mL), dried over magnesium sulfate, filtered and concentrated in vacuo. Column chromatography eluting with 10% EtOAc/PE resulted in a colourless oil (0.305 g, 57%, de ⩾95%). R_f (20% EtOAc/PE) 0.25. $[\alpha]_D^{18} = -64.4$ (*c* 0.8, $CHCl_3$). ν_{max} (cm^{-1}) 3370 (OH), 3047, 2974, 2302, 1719 (C=O), 1421. ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.63 (1H, dt, $J = 6.0, 1.5$), 5.53 (1H, dt, $J = 6.0, 1.5$), 4.49 (1H, app. t, $J = 4.2$), 4.41–4.38 (1H, m), 4.26–4.30 (1H, m), 3.43 (1H, br s), 1.95 (3H, s), 1.02 (9H, s). ^{13}C NMR (75 MHz, $CDCl_3$) 173.3, 134.3, 132.8, 92.3, 79.5, 78.3, 74.6, 28.7, 21.3. *m/z* (EI) 215 (M+H). HRMS (ES) calculated for $C_{11}H_{22}O_4N$ (M+NH_4) 232.1549. Found 232.1547.

3.2.2. (3*R*,4*S*,5*S*)-3-^{t}Butoxy-4-acetoxy-5-camphanoxycyclopent-2-ene 4b.

To **4a** (0.28 g, 1.31 mmol) stirring in DCM (2.5 mL) was added 1*S* (−)-camphanoyl chloride (0.34 g, 1.57 mmol) and DMAP (0.032 g, 0.26 mmol). The mixture was cooled to 0 °C, triethylamine (0.217 mL, 1.57 mmol) added and the mixture allowed to warm to room temperature over 6 h then quenched with ammonium chloride (3 mL), extracted with ether (3×5 mL), washed with brine (5 mL), dried over magnesium sulfate, filtered and concentrated in vacuo. Column chromatography eluting with 25–50% Et_2O/PE resulted in a colourless oil (0.39 g, 76%, de ⩾95%). R_f (20% EtOAc/PE) 0.26. $[\alpha]_D^{18} = -13.1$ (*c* 1.0, $CHCl_3$). ν_{max} (cm^{-1}) 2974, 2935, 2874, 1793 (C=O), 1748 (C=O), 1471, 1448, 1367. ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.74 (1H, dt, $J = 5.9, 1.3$), 5.60 (1H, dt, $J = 5.9, 1.5$), 5.52–5.50 (1H, m), 5.04 (1H, app. t, $J = 3.8$), 4.44–4.42 (1H, m), 2.30–2.21 (1H, m), 1.93 (3H, s), 1.90–1.70 (2H, m), 1.55–1.46 (1H, m), 1.04 (9H, s), 0.94 (6H, s), 0.82 (3H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 178.5, 170.5, 167.1, 137.7, 129.5, 91.4, 86.0, 81.7, 78.5, 75.0, 55.2, 54.7, 31.0, 29.4, 28.5, 21.2, 17.0, 16.8, 10.1. *m/z* (EI) 294 (M−C_4H_9, C_2H_3O). HRMS (ES) calculated for $C_{21}H_{34}O_7N$ (M+NH_4) 412.2335. Found 412.2331.

Determination of ee of (+)-**1**:

3.2.3. (3*S*,4*S*,5*R*)-3-^{t}Butoxy-4,5-dihydroxy-cyclopent-1-ene 5.

To (+)-**1** (0.33 g, 1.94 mmol) stirring in methanol (3.5 mL) at 0 °C was added $CeCl_3{\cdot}7H_2O$ (1.01 g, 2.72 mmol) followed by $NaBH_4$ (0.103 g, 2.72 mmol) portionwise over 15 min. The mixture was stirred for 30 min then quenched with ammonium chloride (5 mL, saturated solution), extracted with ethyl acetate (3×5 mL), washed with brine (10 mL), dried over magnesium sulfate, filtered and concentrated in vacuo. Column chromatography eluting with 25–70% EtOAc/PE resulted in **5** as the major diastereomer as a colourless oil (0.156 g, 48%). R_f (30% EtOAc/PE) 0.31. $[\alpha]_D^{18} = +11.4$ (*c* 0.35, $CHCl_3$). ν_{max} (cm^{-1}) 2974, 2856, 1443, 1380, 1347. ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.73 (1H, dt, $J = 6.0, 1.5$), 5.67 (1H, dt, $J = 6.0, 1.5$), 4.40–4.35 (1H, m), 4.25–4.23 (1H, m), 3.89 (1H, app. q, $J = 4.5$), 2.42 (1H, d, $J = 5.1$), 2.16 (1H, d, $J = 8.1$), 1.18 (9H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 135.0, 133.6, 88.5, 80.4, 80.2, 74.7, 28.8. *m/z* (ES) 172 (M+). HRMS (ES) calculated for $C_9H_{20}O_3N$ (M+NH_4) 190.1443. Found 190.1446.

3.2.4. (3*S*,4*R*,5*R*)-3-^{t}Butoxy-4,5-biscamphanoxy-cyclopent-2-ene 6.

To **5** (0.141 g, 0.84 mmol) stirring in DCM (4 mL) at 0 °C was added (1*S*)-(−)-camphanoyl chloride (0.654 g, 3 mmol), DMAP (0.031 g, 0.25 mmol) and triethylamine (0.277 mL, 2 mmol). The mixture was allowed to warm to room temperature for 1 h then quenched with ammonium chloride (4 mL, saturated solution), extracted with ether (3×5 mL), washed with brine (10 mL), dried over magnesium sulfate, filtered and concentrated in vacuo. Column chromatography eluting with 25–40% Et_2O/PE resulted in a white solid, mp 120–123 °C (0.404 g, 90%, de ⩾95%). R_f (30% EtOAc/PE) 0.54. $[\alpha]_D^{18} = +24.2$ (*c* 0.75, $CHCl_3$). ν_{max} (cm^{-1}) 2369, 2375, 1787 (C=O), 1736 (C=O), 1421. ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.72–5.70 (1H, m), 5.56–5.54 (2H, m), 5.13–5.11 (1H, m), 4.52–4.51 (1H, m), 2.31–2.21 (2H, m), 1.93–1.65 (4H, m), 1.57–1.43 (2H, m), 1.00–0.81 (27H, m). ^{13}C NMR (300 MHz, $CDCl_3$) δ 178.9, 178.0, 171.9, 167.3, 137.7, 129.2, 91.3,

91.2, 87.6, 81.2, 78.5, 75.3, 55.4, 54.9, 31.1, 29.3, 28.6, 17.0, 10.1. m/z (EI) 476 ($M-C_4H_8$). HRMS (CI) calculated for $C_{29}H_{44}O_9N$ ($M+NH_4$) 550.3016. Found 550.3016.

3.3. 1-(*para*-Methoxy)phenoxy-5-′butoxy-penta-1,4-dien-3-one 7

To (±)-**1** (0.19 g, 1.12 mmol) stirring in THF (8 mL) was added PPh_3 (0.44 g, 1.68 mmol) followed by 4-methoxyphenol (0.209 g, 1.68 mmol). The reaction mixture was cooled to 0 °C and DIAD (0.264 mL, 1.34 mmol) added. The reaction mixture was allowed to warm slowly to room temperature over 16 h then concentrated in vacuo. Column chromatography eluting with 10% EtOAc/PE resulted in a yellow oil (0.042 g, 14%). R_f (20% EtOAc/PE) 0.46. ν_{max} (cm^{-1}) 2974, 2929, 1727 (C=O), 1502 (C=C). ^1H NMR (300 MHz, $CDCl_3$) δ 7.77 (1H, d, $J = 11.7$), 7.73 (1H, d, $J = 12.1$), 7.0 (2H, d, $J = 9.1$), 6.88 (2H, d, $J = 9.1$), 5.89 (1H, d, $J = 12.1$), 5.79 (1H, d, $J = 11.7$), 3.80 (3H, s), 1.38 (9H, s). ^{13}C NMR (75 MHz, $CDCl_3$) δ 189.3, 158.9, 158.0, 157.1, 150.3, 119.6, 115.2, 111.0, 108.0, 80.6, 56.1, 28.6. m/z (FAB) 277 (M+H). HRMS (ES) calculated for $C_{16}H_{21}O_4$ (M+H) 277.1440. Found 277.1444.

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