

Supporting Information

Total synthesis of capsanthin and capsorubin using Lewis acid-promoted regio- and stereoselective rearrangement of tetrasubstituted epoxides.

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Synthesis and characterization data of compounds **7d-f**, **8d,f**, **9d,e**, **11**, **14-17** and **5**

Spectral data of compounds **1** and **2**

Ethyl (2*E*,4*E*)-3-Methyl-5-(2,2,6-trimethyl-7-oxobicyclo[4.1.0]hept-1-yl)penta-2,4-dienoate 7d

A solution of the triethyl phosphonoacetate in dry THF (15 ml) was added dropwise to a stirred suspension of NaH (60% oil dispersion; 880 mg, 22 mmol) in dry THF (20 ml) at 0 °C. After being stirred at 0 °C for 15 min, a solution of the β -ionone **10** (2.50 g, 13 mmol) in dry THF (15 ml) was added to it. The reaction mixture was then warm to 50 °C and stirring was continued for 3 h. The reaction was quenched by addition of saturated aq. NH₄Cl and the mixture was extracted with ether. The extracts were washed with brine, dried and evaporated to give a residue, which was purified by CC (ether-hexane, 7:93) to afford the corresponding conjugated ester as an isomeric mixture (2.40 g, 70%; all-*E*:9*Z*, ~8:1). To an ice-cooled solution of this ester in CH₂Cl₂ (20 ml) was added a solution of MCPBA (70%; 2.71 g, 17.8 mmol) in CH₂Cl₂ (15 ml) and the mixture was stirred at rt for 2 h. After addition of 1% aq. Na₂S₂O₃, CH₂Cl₂ was evaporated and the resulting mixture was extracted with ether. The extracts were washed with saturated aq. NaHCO₃ and brine. Evaporation of the dried solvent gave a residue, which was purified by CC (ether-hexane, 1:9) to give the epoxy dienoate **7d** (1.72 g, 48% from **10**) and its 9*Z*-isomer (230 mg, 6% from **10**) as colorless oils, respectively.

Compound 7d: λ_{\max} (EtOH)/nm 265; ν_{\max} /cm⁻¹ 1703 (conj. OCO), 1634 and 1613 (C=C); δ_{H} (300 MHz) 0.92 and 1.11 and 1.13 (each 3H, s, *gem*-Me and 5-Me), 1.28 (3H, t, *J* 7, CH₂CH₃), 1.08 (1H, m), 1.37–1.52 (3H, m) and 1.70–1.96 (2H, m) (2-H₂, 3-H₂ and 4-H₂), 2.29 (3H, d, *J* 1, 9-Me), 4.17 (2H, q, *J* 7, CH₂CH₃), 5.79 (1H, q-like, *J* 1, 10-H), 6.26 and 6.32 (each 1H, d, *J* 16, 7-H and 8-H); *m/z* (EI) 278.1905 (M⁺, C₁₇H₂₆O₃ requires 278.1880).

9*Z*-Isomer of compound 7d: λ_{\max} (EtOH)/nm 266; ν_{\max} /cm⁻¹ 1703 (conj. OCO), 1636 and 1604 (C=C); δ_{H} (300 MHz) 0.97, 1.10 and 1.18 (each 3H, s, *gem*-Me and 5-Me), 1.28 (3H, t, *J* 7, CH₂CH₃), 1.07 (1H, m), 1.37–1.55 (3H, m) and 1.70–1.96 (2H, m) (2-H₂, 3-H₂ and 4-H₂), 2.00 (3H, d, *J* 1, 9-Me), 4.17 (2H, q, *J* 7, CH₂CH₃), 5.69 (1H, br s, 10-H), 6.24 (1H, d, *J* 16, 7-H), 7.59 (1H, d, *J* 16, 8-H); *m/z* (EI) 278.1898 (M⁺, C₁₇H₂₆O₃ requires 278.1880).

(2*E*,4*E*)-3-Methyl-5-(2,2,6-trimethyl-7-oxobicyclo[4.1.0]hept-1-yl)penta-2,4-dienal 7e

A solution of the ester **7d** (1.11 g, 4.0 mmol) in dry ether (20 ml) was added dropwise to a stirred suspension of LiAlH₄ (152 mg, 4.0 mmol) in dry ether at 0 °C. After being stirred at 0 °C for 15 min, the excess of

LiAlH₄ was decomposed by dropwise addition of water and the mixture was extracted with ether. The extracts were dried and evaporated to give a residue, which without purification was dissolved in ether-hexane (~1:4) and shaken with MnO₂ (5 g) at rt for 5 h. The mixture was filtered through Celite. Evaporation of the filtrate followed by purification by SCC (ether-hexane, 3:7) to provide the epoxy dienal **7e** (898 mg, 96%) as a pale yellow oil; $\lambda_{\max}(\text{EtOH})/\text{nm}$ 284; $\nu_{\max}/\text{cm}^{-1}$ 1662 (conj. CHO), 1629 and 1598 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 0.94, 1.13 and 1.15 (each 3H, s, *gem*-Me and 5-Me), 1.08 (1H, m), 1.38–1.53 (3H, m) and 1.72–1.98 (2H, m) (2-H₂, 3-H₂ and 4-H₂), 2.28 (3H, d, *J* 1, 9-Me), 5.98 (1H, br d, *J* 8, 10-H), 6.38 and 6.49 (each 1H, d, *J* 16, 7-H and 8-H), 10.13 (1H, d, *J* 8, CHO); *m/z* (EI) 234.1637 (M⁺, C₁₅H₂₂O₂ requires 234.1619).

Ethyl (2E,4E,6E)-5-Methyl-7-(2,2,6-trimethyl-7-oxobicyclo[4.1.0]hept-1-yl)hepta-2,4,6-trienoate 11

To a solution of triethyl phosphonoacetate (935 mg, 4.2 mmol) in dry THF (7 ml) was added BuLi (1.6 M in hexane; 2.71 ml, 4.3 mmol) at 0 °C. After being stirred at 0 °C for 15 min, a solution of the epoxy dienal **7e** (650 mg, 2.8 mmol) in dry THF (5 ml) was added to the reaction mixture at 0 °C and stirring was continued for 15 min. After being quenched with saturated aq. NH₄Cl, the mixture was extracted with ether. The extracts were washed with brine, dried and evaporated to give the residue, which was purified by SCC (ether-hexane, 1:9) to provide the epoxy trienoate **11** (701 mg, 83%) as a pale yellow oil; $\lambda_{\max}(\text{EtOH})/\text{nm}$ 311; $\nu_{\max}/\text{cm}^{-1}$ 1698 (conj. OCO), 1634 and 1610 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 0.93, 1.11 and 1.14 (each 3H, s, *gem*-Me and 5-Me), 1.30 (3H, t, *J* 7, CH₂CH₃), 1.07 (1H, m), 1.37–1.52 (3H, m) and 1.67–1.96 (2H, m) (2-H₂, 3-H₂ and 4-H₂), 2.01 (3H, br s, 9-Me), 4.21 (2H, q, *J* 7, CH₂CH₃), 5.90 (1H, d, *J* 15.5, 12-H), 6.11 and 6.32 (each 1H, d, *J* 15.5, 7-H and 8-H), 6.19 (1H, br d, *J* 11.5, 10-H), 7.67 (1H, dd, *J* 15.5 and 11.5, 11-H); *m/z* (EI) 304.2020 (M⁺, C₁₉H₂₈O₃ requires 304.2037).

(2E,4E,6E)-5-Methyl-7-(2,2,6-trimethyl-7-oxobicyclo[4.1.0]hept-1-yl)hepta-2,4,6-trienal 7f

Following the procedure described for the preparation of the epoxy dienal **7e**, reduction of the epoxy trienoate **11** (852 mg) with LiAlH₄ followed by oxidation with MnO₂ provided the epoxy trienal **7f** (650 mg, 89%) as a yellow oil; $\lambda_{\max}(\text{EtOH})/\text{nm}$ 326; $\nu_{\max}/\text{cm}^{-1}$ 1673 (conj. CHO), 1602 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 0.94, 1.12 and 1.15 (each 3H, s, *gem*-Me and 5-Me), 1.08 (1H, m), 1.38–1.53 (3H, m) and 1.70–1.97 (2H, m) (2-H₂, 3-H₂ and 4-H₂), 2.06 (3H, d, *J* 1, 9-Me), 6.19 (1H, dd, *J* 15.5 and 8, 12-H), 6.22 and 6.38 (each 1H, d, *J*

15.5, 7-H and 8-H), 6.33 (1H, br d, J 11.5, 10-H), 7.50 (1H, dd, J 15.5 and 11.5, 11-H), 9.62 (1H, d, J 8, CHO); m/z (EI) 260.1776 (M^+ , $C_{17}H_{24}O_2$ requires 260.1775).

Treatment of the epoxy dienoate **7d** with $SnCl_4$

To a solution of the epoxy dienoate **7d** (150 mg, 0.54 mmol) in dry CH_2Cl_2 (5 ml) was added $SnCl_4$ (1M in CH_2Cl_2 ; 1.2 ml, 1.2 mmol) at 0 °C. The mixture was stirred at 0 °C for 20 min and then poured into saturated aq. $NaHCO_3$ and extracted with ether. The extracts were washed with brine and dried. Evaporation of the solvent gave a residue, which was purified by SCC (ether-hexane, 1:9) to afford the 5,8-epoxide **8d** (129 mg, 86%; 5,8-*trans*:5,8-*cis*, ~8:1) and the cyclopentyl ketone **9d** (8 mg, 5%). A part of the diastereomeric mixture of **8d** was separated by PHPLC [LiChrosorb Si 60 (7 μ m) 2 \times 25 cm; ether-hexane, 12:88] to provide each pure isomer, as a colorless oil, respectively.

5,8-Trans-isomer of 8d: λ_{max} (EtOH)/nm 215; ν_{max}/cm^{-1} 1708 (conj. OCO), 1656 (C=C); δ_H (300 MHz) 1.10 and 1.14 (each 3H, s, *gem*-Me), 1.27 (3H, t, J 7, CH_2CH_3), 1.44 (3H, s, 5-Me), 1.20 (1H, m), 1.46–1.69 (4H, m) and 1.98 (1H, m) (2- H_2 , 3- H_2 and 4- H_2), 2.10 (3H, d, J 1, 9-Me), 4.16 (2H, q, J 7, CH_2CH_3), 5.12 (1H, br s, 8-H), 5.22 (1H, br s, 7-H), 5.96 (1H, quint-like, J 1, 10-H); m/z (EI) 278.1877 (M^+ , $C_{17}H_{26}O_3$ requires 278.1880).

5,8-Cis-isomer of 8d: λ_{max} (EtOH)/nm 216; ν_{max}/cm^{-1} 1709 (conj. OCO), 1656 (C=C); δ_H (300 MHz) 1.09 and 1.17 (each 3H, s, *gem*-Me), 1.28 (3H, t, J 7, CH_2CH_3), 1.47 (3H, s, 5-Me), 1.20 (1H, m), 1.44–1.77 (4H, m) and 1.95 (1H, m) (2- H_2 , 3- H_2 and 4- H_2), 2.12 (3H, s, 9-Me), 4.16 (2H, q, J 7, CH_2CH_3), 5.04 (1H, br s, 8-H), 5.31 (1H, d, J 2, 7-H), 5.99 (1H, quint-like, J 1, 10-H); m/z (EI) 278.1877 (M^+ , $C_{17}H_{26}O_3$ requires 278.1880).

Compound 9d: λ_{max} (EtOH)/nm 279; ν_{max}/cm^{-1} 1709 (conj. OCO), 1676 (conj. CO), 1616 and 1594 (C=C); δ_H (300 MHz) 0.85, 1.10 and 1.19 (each 3H, s, *gem*-Me and 5-Me), 1.30 (3H, t, J 7, CH_2CH_3), 1.45–1.78 (5H, m) and 2.48 (1H, m) (2- H_2 , 3- H_2 and 4- H_2), 2.30 (3H, d, J 1, 9-Me), 4.20 (2H, q, J 7, CH_2CH_3), 6.07 (1H, br s, 10-H), 6.79 (1H, d, J 15.5, 7-H), 7.18 (1H, d, J 15.5, 8-H); m/z (EI) 278.1880 (M^+ , $C_{17}H_{26}O_3$ requires 278.1880).

Treatment of the epoxy dienoate **7d** with tris(4-bromophenyl)aminium hexachloroantimonate

To a solution of the epoxy dienolate **7d** (150 mg, 0.54 mmol) in dry dry CH₂Cl₂ (5 ml) was added tris(4-bromophenyl)aminium hexachloroantimonate (44 mg, 0.054 mmol) at rt. The mixture was stirred at rt for 15 min and concentrated to give a residue, which was purified by SCC (ether-hexane, 1:9) to afford the 5,8-epoxide **8d** (113 mg, 75%; 5,8-*trans*:5,8-*cis*, ~8:1) and the cyclopentyl ketone **9d** (2 mg, 1%).

Treatment of the epoxy dienol **7e** with SnCl₄

In the same manner as described for SnCl₄-treatment of the epoxy dienolate **7d**, the epoxy dienol **7e** (150 mg) was treated with SnCl₄ to give crude products, which were purified by SCC (ether-hexane, 3:7) to afford the cyclopentyl ketone **9e** (137 mg, 91%) as a pale yellow oil; $\lambda_{\max}(\text{EtOH})/\text{nm}$ 287; $\nu_{\max}/\text{cm}^{-1}$ 1667 (conj. CO + conj. CHO), 1589 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 0.86, 1.11 and 1.20 (each 3H, s, *gem*-Me and 5-Me), 1.47–1.81 (5H, m) and 2.48 (1H, m) (2-H₂, 3-H₂ and 4-H₂), 2.32 (3H, d, *J* 1, 9-Me), 6.21 (1H, br d, *J* 8, 10-H), 6.90 (1H, d, *J* 15.5, 7-H), 7.25 (1H, d, *J* 15.5, 8-H), 10.18 (1H, d, *J* 8, CHO); $\delta_{\text{C}}(75 \text{ MHz})$ 13.28 (9-CH₃), 19.64, 34.36 and 40.41 (C2, C3 and C4), 20.49, 24.56 and 25.50 (*gem*-CH₃ and 5-CH₃), 44.20 (C1), 59.21 (C5), 128.72 (C7), 134.18 (C10), 143.47 (C8), 151.47 (C9), 191.11 (C11), 203.30 (C6); *m/z* (EI) 234.1616 (M⁺, C₁₅H₂₂O₂ requires 234.1618).

Treatment of the epoxy dienol **7f** with SnCl₄

In the same manner as described for SnCl₄-treatment of the epoxy dienolate **7d**, the epoxy trienal **7f** (307 mg) was treated with SnCl₄. Purification of the crude products by SCC (ether-hexane, 2:3) afforded the 5,8-epoxide **8f** (211 mg, 69%; 5,8-*trans*:5,8-*cis*, 5:1), a part of which was separated by PHPLC [LiChrosorb Si 60 (7 μm) 2 \times 25 cm; THF-hexane, 8:92] to provide each pure isomer as a pale yellow oil, respectively.

5,8-*Trans*-isomer of **8f:** $\lambda_{\max}(\text{EtOH})/\text{nm}$ 284; $\nu_{\max}/\text{cm}^{-1}$ 1678 (conj. CHO), 1633 and 1596 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 1.12 and 1.16 (each 3H, s, *gem*-Me), 1.45 (3H, s, 5-Me), 1.22 (1H, m), 1.50–1.70 (4H, m) and 2.00 (1H, m) (2-H₂, 3-H₂ and 4-H₂), 1.89 (3H, d, *J* 1, 9-Me), 5.21 (2H, br s, 7-H and 8-H), 6.16 (1H, dd, *J* 15 and 8, 12-H), 6.41 (1H, br d, *J* 11.5, 10-H), 7.42 (1H, dd, *J* 15 and 11.5, 11-H), 9.60 (1H, d, *J* 8, CHO); *m/z* (EI) 260.1789 (M⁺, C₁₇H₂₄O₂ requires 260.1775).

5,8-*Cis*-isomer of **8f:** $\lambda_{\max}(\text{EtOH})/\text{nm}$ 285; $\nu_{\max}/\text{cm}^{-1}$ 1678 (conj. CHO), 1633 and 1595 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 1.10 and 1.19 (each 3H, s, *gem*-Me), 1.47 (3H, s, 5-Me), 1.22 (1H, m), 1.48–1.72 (4H, m) and 1.96

(1H, m) (2-H₂, 3-H₂ and 4-H₂), 1.93 (3H, d, *J* 1, 9-Me), 5.11 (1H, br s, 8-H), 5.28 (1H, d, *J* 2, 7-H), 6.16 (1H, dd, *J* 15 and 8, 12-H), 6.43 (1H, br d, *J* 11.5, 10-H), 7.42 (1H, dd, *J* 15 and 11.5, 11-H), 9.60 (1H, d, *J* 8, CHO); *m/z* (EI) 260.1761 (M⁺, C₁₇H₂₄O₂ requires 260.1775).

(1R)-3,5,5-Trimethyl-4-[(1E)-2-(tributylstannyl)ethenyl]cyclohex-3-enol 14

To a mixture of the alkyne **13**¹³ (1.50 g, 9.15 mmol) and tributyltin hydride (3.70 ml, 13.7 mmol) was added AIBN (50 mg, 0.3 mmol) and the mixture was heated at 130 °C for 20 min. After cooling, the mixture was purified by low-pressure CC (acetone-hexane, 15:85) to give the vinylstannane **14** (3.68 g, 88%) as a colorless oil; [α]_D²⁵ -69.9 (*c* 1.03, MeOH); ν_{max}/cm⁻¹ 3606 and 3445 (OH), 1579 (C=C); δ_H(300 MHz) 0.85–1.58 (27H, m, Bu×3), 1.04 and 1.05 (each 3H, s, *gem*-Me), 1.43 (1H, t, *J* 12, 2-H_{ax}), 1.69 (3H, s, 5-Me), 1.75 (1H, ddd, *J* 12, 3.5 and 2, 2-H_{eq}), 2.00 (1H, br dd, *J* 16.5 and 8.5, 4-H_{ax}), 2.34 (1H, br dd, *J* 16.5 and 5.5, 4-H_{eq}), 3.98 (1H, m, 3-H), 5.89 (1H, d, *J* 20, ¹H–¹¹⁷Sn=¹H–¹¹⁹Sn=84, 8-H), 6.31 (1H, br d, *J* 20, ¹H–¹¹⁷Sn=¹H–¹¹⁹Sn=65, 7-H).

Ethyl (2E,4E)-5-[(4R)-4-Hydroxy-2,6,6-trimethylcyclohex-1-enyl]-3-methylpenta-2,4-dienoate 15

A suspension of the vinylstannane **14** (1.12 g, 2.46 mmol), the vinyltriflate **23**¹⁷ (970 mg, 3.70 mmol), AsPh₃ (150 mg, 0.49 mmol) and Pd₂dba₂•CHCl₃ (64 mg, 0.062 mmol) in DMF (5 ml) was stirred at 50 °C for 4 h. The mixture was diluted with ether and washed with brine. Evaporation of the dried solution gave a residue, which was purified by SCC (acetone-hexane, 15:85) to afford the dienoate **15** (629 mg, 92%) as a pale yellow oil; [α]_D²⁶ -94.5 (*c* 1.10, MeOH); λ_{max}(EtOH)/nm 259 and 296; ν_{max}/cm⁻¹ 3607 and 3461 (OH), 1702 (conj. OCO), 1607 (C=C); δ_H(300 MHz) 1.06 and 1.07 (each 3H, s, *gem*-Me), 1.29 (3H, t, *J* 7, CH₂CH₃), 1.48 (1H, t, *J* 12, 2-H_{ax}), 1.71 (3H, s, 5-Me), 1.78 (1H, ddd, *J* 12, 4 and 2, 2-H_{eq}), 2.05 (1H, br dd, *J* 17 and 9, 4-H_{ax}), 2.33 (3H, d, *J* 1, 9-Me), 2.39 (1H, br dd, *J* 17 and 5.5, 4-H_{eq}), 4.00 (1H, m, 3-H), 4.18 (2H, q, *J* 7, CH₂CH₃), 5.75 (1H, br s, 10-H), 6.09 (1H, d, *J* 16, 8-H), 6.50 (1H, d, *J* 16, 7-H); *m/z* (EI) 278.1891 (M⁺, C₁₇H₂₆O₃ requires 278.1881).

Ethyl (2E,4E)-5-[(4R)-4-*tert*-Butyldimethylsilyloxy-2,6,6-trimethylcyclohex-1-enyl]-3-methylpenta-2,4-dienoate 16

A solution of TBSCl (1.17 g, 7.76 mmol) in dry CH₂Cl₂ (5 ml) was added slowly to a stirred solution of the hydroxy compound **15** (1.44 g, 5.18 mmol), 4-dimethylaminopyridine (DMAP) (760 mg, 6.2 mmol) and Et₃N (0.87 ml, 6.2 mmol) in dry CH₂Cl₂ (10 ml) at 0 °C. The mixture was stirred at rt for 1 h, poured into chilled water and extracted with ether. The extracts were washed successively with aq. 3% HCl, saturated aq. NaHCO₃ and brine. Evaporation of the dried solution gave a residue, which was purified by SCC (ether-hexane, 5:95) to afford the TBS ether **16** (1.86 g, 92%) as a pale yellow oil; $[\alpha]_D^{26} -80.2$ (*c* 1.03, MeOH); $\lambda_{\max}(\text{EtOH})/\text{nm}$ 258 and 296; $\nu_{\max}/\text{cm}^{-1}$ 1703 (conj. OCO), 1607 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 0.08 (6H, s, SiMe₂), 0.91 (9H, s, *tert*-Bu), 1.04 and 1.06 (each 3H, s, *gem*-Me), 1.29 (3H, t, *J* 7, CH₂CH₃), 1.50 (1H, t, *J* 12, 2-H_{ax}), 1.67 (1H, ddd, *J* 12, 3.5 and 2, 2-H_{eq}), 1.70 (3H, s, 5-Me), 2.07 (1H, br dd, *J* 17.5 and 9.5, 4-H_{ax}), 2.05 (1H, br dd, *J* 17.5 and 6, 4-H_{eq}), 2.33 (3H, d, *J* 1, 9-Me), 3.95 (1H, m, 3-H), 4.18 (2H, q, *J* 7, CH₂CH₃), 5.74 (1H, br s, 10-H), 6.09 (1H, d, *J* 16, 8-H), 6.50 (1H, d, *J* 16, 7-H); *m/z* (EI) 392.2743 (M⁺, C₂₃H₄₀O₃Si requires 392.2744).

Epoxidation of the ester **16**

A solution of MCPBA (80%, 2.48 g, 11.5 mmol) in CH₂Cl₂ (30 ml) was added dropwise to an ice-cooled solution of the ester **16** (4.09 g, 10.4 mmol) in CH₂Cl₂ (30 ml) and the mixture was stirred at 0 °C for 1 h. After the reaction mixture was quenched with aq. 10% Na₂S₂O₃, CH₂Cl₂ was evaporated off and the organics were extracted with ether. The extracts were washed with saturated aq. NaHCO₃ and brine. Evaporation of the dried extracts gave a residue, which was purified by CC (CH₂Cl₂-ether, 98.5:1.5) to afford the *anti*-epoxide **17a** (1.18 g, 28%) and the *syn*-epoxide **17b** (2.77 g, 65%) as colorless oils.

Compound 17a: $[\alpha]_D^{21} -58.4$ (*c* 1.06, MeOH); $\lambda_{\max}(\text{EtOH})/\text{nm}$ 264; $\nu_{\max}/\text{cm}^{-1}$ 1704 (conj. OCO), 1634 and 1613 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 0.05 (6H, s, SiMe₂), 0.88 (9H, s, *tert*-Bu), 0.95, 1.14 and 1.15 (each 3H, s, *gem*-Me and 5-Me), 1.26 (1H, dd, *J* 13 and 10, 2-H_{ax}), 1.28 (3H, t, *J* 7, CH₂CH₃), 1.51 (1H, ddd, *J* 13, 3.5 and 1.5, 2-H_{eq}), 1.65 (1H, dd, *J* 14 and 8, 4-H_{ax}), 2.25 (1H, ddd, *J* 14, 5 and 1.5, 4-H_{eq}), 2.29 (3H, d, *J* 1, 9-Me), 3.85 (1H, m, 3-H), 4.17 (2H, q, *J* 7, CH₂CH₃), 5.79 (1H, br s, 10-H), 6.25 and 6.33 (each 1H, d, *J* 15.5, 7-H and 8-H); *m/z* (EI) 408.2711 (M⁺, C₂₃H₄₀O₄Si requires 408.2693).

Compound 17b: $[\alpha]_D^{23} +5.7$ (*c* 1.05, MeOH); $\lambda_{\max}(\text{EtOH})/\text{nm}$ 264; $\nu_{\max}/\text{cm}^{-1}$ 1703 (conj. OCO), 1634 and 1613 (C=C); $\delta_{\text{H}}(300 \text{ MHz})$ 0.05 (6H, s, SiMe₂), 0.88 (9H, s, *tert*-Bu), 0.95, 1.14 and 1.17 (each 3H, s,

gem-Me and 5-Me), 1.22 (1H, ddd, *J* 12.5, 4 and 1.5, 2-H_{eq}), 1.28 (3H, t, *J* 7, CH₂CH₃), 1.57 (1H, t, *J* 12.5, 2-H_{ax}), 1.86 (1H, dd, *J* 15 and 9.5, 4-H_{ax}), 2.08 (1H, ddd, *J* 15, 7 and 1.5, 4-H_{eq}), 2.28 (3H, d, *J* 1, 9-Me), 3.84 (1H, m, 3-H), 4.17 (2H, q, *J* 7, CH₂CH₃), 5.79 (1H, d-like, *J* 1, 10-H), 6.22 and 6.29 (each 1H, d, *J* 16, 7-H and 8-H); *m/z* (EI) 408.2708 (M⁺, C₂₃H₄₀O₄Si requires 408.2693).

Preparation of the epoxy dienolate **17a** from the epoxy aldehyde **18**

To a solution of the phosphonate **24** (1.33 g, 5.03 mmol) in dry THF (10 ml) was added *n*-BuLi (1.58 M in hexane; 3.2 ml, 5.06 mmol) at 0 °C and the mixture was stirred for a further 15 min. A solution of the aldehyde **18**²¹ (1.00 g, 3.36 mmol) was added to this mixture and the mixture was stirred at 0 °C for 20 min. After being quenched with saturated aq. NH₄Cl, the mixture was extracted with ether. The extracts were washed with brine, dried and evaporated to give the residue, which was purified by CC (ether-hexane, 15:85) to provide the epoxy dienolate **17a** (920 mg, 67%) and its 9*Z*-isomer (351 mg, 26%) as pale yellow oils.

9*Z*-Isomer of 17a: [α]_D²² -21.4 (*c* 0.94, MeOH); λ_{\max} (EtOH)/nm 265; ν_{\max} /cm⁻¹ 1703 (conj. OCO), 1636 and 1604 (C=C); δ_{H} (300 MHz) 0.04 (6H, s, SiMe₂), 0.87 (9H, s, *tert*-Bu), 0.98, 1.12 and 1.18 (each 3H, s, *gem*-Me and 5-Me), 1.24 (1H, dd, *J* 13 and 10, 2-H_{ax}), 1.27 (3H, t, *J* 7, CH₂CH₃), 1.51 (1H, ddd, *J* 13, 3.5 and 1.5, 2-H_{eq}), 1.64 (1H, dd, *J* 14 and 8, 4-H_{ax}), 1.99 (3H, d, *J* 1, 9-Me), 2.24 (1H, ddd, *J* 14, 5 and 1.5, 4-H_{eq}), 3.86 (1H, m, 3-H), 4.15 (2H, q, *J* 7, CH₂CH₃), 5.68 (1H, br s, 10-H), 6.25 (1H, dd, *J* 16 and 0.5, 7-H), 7.58 (1H, dd, *J* 16 and 0.5, 8-H); *m/z* (EI) 408.2696 (M⁺, C₂₃H₄₀O₄Si requires 408.2693).

(2*E*,4*E*)-3-Methyl-5-[(1*S*,4*S*,6*R*)-4-*tert*-butyldimethylsilyloxy-2,2,6-trimethyl-7-oxabicyclo[4.1.0]hept-1-yl]penta-2,4-dienal **5**

Following the procedure described for the preparation of the epoxy dienal **7e**, reduction of the epoxy dienolate **15a** (690 mg) with LiAlH₄ followed by oxidation with MnO₂ provided the crude products, which were purified by SCC (acetone-hexane, 1:4) to give the epoxy dienal **5** (604 nmg, 98%) as a pale yellow oil; [α]_D²¹ -65.8 (*c* 1.09, MeOH); λ_{\max} (EtOH)/nm 282; ν_{\max} /cm⁻¹ 1662 (conj. CHO), 1630 and 1598 (C=C); δ_{H} (300 MHz) 0.05 and 0.06 (each 3H, s, SiMe₂), 0.88 (9H, s, *tert*-Bu), 0.96 (3H, s) and 1.17 (6H, s) (*gem*-Me and 5-Me), 1.27 (1H, dd, *J* 13 and 10, 2-H_{ax}), 1.52 (1H, ddd, *J* 13, 3.5 and 1.5, 2-H_{eq}), 1.67 (1H,

dd, J 14.5 and 8, 4- H_{ax}), 2.26 (1H, ddd, J 14.5, 5 and 1.5, 4- H_{eq}), 2.28 (3H, d, J 1, 9-Me), 3.86 (1H, m, 3-H), 5.97 (1H, br d, J 8, 10-H), 6.37 and 6.50 (each 1H, d, J 15.5, 7-H and 8-H), 10.13 (1H, s, J 8, CHO); m/z (EI) 364.2439 (M^+ , $C_{21}H_{36}O_3Si$ requires 364.2432).

Preparation of the Wittig salt 20

A solution of the ester **15** (1.00 g, 3.6 mmol) in dry ether (40 ml) were added dropwise to a stirred suspension of $LiAlH_4$ (165 mg, 4.3 mmol) in dry ether at 0 °C. After being stirred at 0 °C for 15 min, the excess of $LiAlH_4$ was decomposed by dropwise addition of water and the mixture was extracted with ether. The extracts were dried and evaporated to give a residue, which was purified by SCC (acetone-hexane, 3:7) to afford the corresponding alcohol (723 mg, 85%). A solution of this alcohol (3.1 ml) and triphenylphosphine hydrobromide (1.05 g, 3.1 ml) in MeOH (20 ml) was stirred at rt for 48 h. Evaporation of the methanol gave a residue, which was washed with ether to provide crude phosphonium salt **20**²⁵;

δ_H (300 MHz) 0.97 and 0.99 (each 3H, s, *gem*-Me), 1.39 (3H, d, J 4, 9-Me), 1.45 (1H, t, J 12, 2- H_{ax}), 1.62 (3H, s, 5-Me), 1.78 (1H, br d, J 12, 2- H_{eq}), 2.03 (1H, br dd, J 16.5 and 9.5, 4- H_{ax}), 2.35 (1H, br dd, J 16.5 and 5.5, 4- H_{eq}), 3.99 (1H, m, 3-H), 4.77 (2H, br dd, J 15.5, 7.5, 11- H_2), 5.33 (1H, br q-like, J 7, 10-H), 5.93 (2H, s, 7-H and 8-H), 7.5-7.9 (15H, m, ArH).

Spectral data of compound 1: λ_{max} (EtOH)/nm 289 and 475; λ_{max} (hexane)/nm 284, 352, 445sh, 466 and 493; ν_{max}/cm^{-1} 3608 (OH), 1654 (conj. CO), 1577, 1555 and 1517 (C=C); δ_H (500 MHz) 0.84 (3H, s, 1'- Me_α), 1.08 (6H, s, 1-*gem*-Me), 1.21 (3H, s, 1'- Me_β), 1.37 (3H, s, 5'-Me), 1.48 (1H, t, J 12, 2- H_{ax}), 1.49 (1H, dd, J 14.5 and 3.5, 4'- H_β), 1.71 (1H, dd, J 14 and 5, 2'- H_β), 1.74 (3H, s, 5-Me), 1.77 (1H, ddd, J 12, 3.5 and 2, 2- H_{eq}), 1.96 (3H, s, 9'-Me), 1.98 (6H, s, 9-Me and 13'-Me), 1.99 (3H, s, 13-Me), 2.00 (1H, dd, J 14 and 7.5, 2'- H_α), 2.05 (1H, br dd, J 16.5 and 9.5, 4- H_{ax}), 2.39 (1H, ddd, J 16.5, 5.5 and 2, 4- H_{eq}), 2.96 (1H, dd, J 14.5 and 8.5, 4'- H_α), 4.00 (1H, m, 3-H), 4.51 (1H, m, 3'-H), 6.13 (2H, s, 7-H and 8-H), 6.16 (1H, br d, J 11.5, 10-H), 6.26 (1H, br d, J 11.5, 14-H), 6.35 (1H, br d, J 11, 14'-H), 6.36 (1H, d, J 14.5, 12-H), 6.44 (1H, d, J 15, 7'-H), 6.52 (1H, d, J 14.5, 12'-H), 6.55 (1H, br d, J 11, 10'-H), 6.61 (1H, dd, J 14.5 and 11, 11'-H), 6.63 (1H, dd, J 14 and 11, 15'-H), 6.68 (1H, dd, J 14.5 and 11.5, 11-H), 6.70 (1H, dd, J 14 and 11.5, 15-H), 7.33 (1H, d, J 15, 8'-H); δ_C (125 MHz) 12.74, 12.79, 12.85 and 12.89 (9- CH_3 , 13- CH_3 , 9'- CH_3 and 13'- CH_3),

21.31 (5'-CH₃), 21.63 (5-CH₃), 25.10 (1'-CH_{3β}), 25.88 (1'-CH_{3α}), 28.75 and 30.27 (1-*gem*-Me), 37.14 (C1), 42.59 (C4), 43.98 (C1'), 45.34 (C4'), 48.47 (C2), 50.90 (C2'), 58.95 (C5'), 65.10 (C3), 70.39 (C3'), 120.92 (C7'), 124.11 (C11'), 125.53 (C11), 125.87 (C7), 126.27 (C5), 129.71 (C15'), 134.24 (C10), 131.64 (C15), 132.38 (C14), 133.66 (C9'), 135.25 (C14'), 135.92 (C13'), 136.13 (C9), 137.40 (C12), 137.61 (C13), 137.77 (C6), 138.45 (C8), 140.68 (C10'), 141.96 (C12'), 146.86 (C8'), 202.91 (C6'); CD (dioxane) nm (Δε) 226 (-3.5), 237 (0), 257 (+4.5), 272 (0), 299 (-5.8), 323 (0), 356 (+1.8), 378 (0); *m/z* (EI) 584.4237 (M⁺, C₄₀H₅₆O₃ requires 584.4226).

Spectral data of compound 2: λ_{max}(EtOH)/nm 301, 483 and 506sh; λ_{max}(hexane)/nm 296, 417sh, 442, 468 and 502; ν_{max}/cm⁻¹ 3612 and 3470 (OH), 1611 (conj. CO), 1584 and 1545 (C=C); δ_H(500 MHz) 0.84 (6H, s, 1-Me_α and 1'-Me_α), 1.21 (6H, s, 1-Me_β and 1'-Me_β), 1.37 (6H, s, 5-Me and 5'-Me), 1.49 (2H, dd, *J* 14.5 and 3.5, 4-H_β and 4'-H_β), 1.71 (2H, dd, *J* 13.5 and 4.5, 2-H_β and 2'-H_β), 1.96 (6H, s, 9-Me and 9'-Me), 1.99 (6H, s, 13-Me and 13'-Me), 2.00 (2H, dd, *J* 13.5 and 7.5, 2-H_α and 2'-H_α), 2.96 (2H, dd, *J* 14.5 and 8.5, 4-H_α and 4'-H_α), 4.51 (2H, m, 3-H and 3'-H), 6.36 (2H, br d-like, *J* 10, 14-H and 14'-H), 6.45 (2H, d, *J* 15.5, 7-H and 7'-H), 6.52 (2H, d, *J* 15, 12-H and 12'-H), 6.55 (2H, br d, *J* 11.5, 10-H and 10'-H), 6.64 (2H, dd, *J* 15 and 11.5, 11-H and 11'-H), 6.69 (2H, m, 15-H and 15'-H), 7.33 (2H, d, *J* 15.5, 8-H and 8'-H); δ_C(125 MHz) 12.81 and 12.88 (9-CH₃, 13-CH₃, 9'-CH₃ and 13'-CH₃), 21.30 (5-CH₃ and 5'-CH₃), 25.10 (1-CH_{3β} and 1'-CH_{3β}), 25.88 (1-CH_{3α} and 1'-CH_{3α}), 43.98 (C1 and C1'), 45.33 (C4 and C4'), 50.89 (C2 and C2'), 58.96 (C5 and C5'), 70.36 (C3 and C3'), 121.13 (C7 and C7'), 124.64 (C11 and C11'), 131.21 (C15 and C15'), 134.05 (C9 and C9'), 134.94 (C14 and C14'), 136.97 (C13 and C13'), 140.51 (C10 and C10'), 141.74 (C12 and C12'), 146.76 (C8 and C8'), 202.93 (C6 and C6'); CD (dioxane)²⁶ nm (Δε) 218 (+0.9), 228 (0), 250 (-0.8), 263 (0), 300 (+3.1), 317 (0), 370 (-1.4); *m/z* (EI) 600.4179 (M⁺, C₄₀H₅₆O₄ requires 600.4176).