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Supporting Information for the Paper

Stereoselective Allylation of 4-oxoazetidine-2-carbaldehydes. Application to the Stereocontrolled Synthesis of Fused Tricyclic β -Lactams via Intramolecular Diels-Alder Reaction of 2-Azetidinone-Tethered Trienes

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General Procedure for the Synthesis of Compounds 2a-h. The corresponding alkoxy- or acetoxyacetylchloride (38 mmol) in anhydrous dichloromethane (25 mL) was added dropwise via syringe to a solution of the corresponding 2,3-*O*-(isopropylidene)-D-glyceraldehyde imine (25 mmol) and Et₃N (75 mmol) in dichloromethane (160 mL), at 0 °C under argon. The resulting mixture was allowed to warm to room temperature, and was stirred for 16 h. The crude mixture was diluted with CH₂Cl₂ (100 mL) and washed with saturated NaHCO₃ (2 x 20 mL) and brine (40 mL). The organic layer was dried (MgSO₄) and concentrated under reduced pressure. Chromatography of the residue eluting with EtOAc/hexanes gave analytically pure compounds **2**. Spectroscopic and analytical data for some representative forms of **2** follow.

(+)-(3R,4S)-3-Acetoxy-4-[(S)-2,2-dimethyl-1,3-dioxolan-4-yl]-1-(p-methoxyphenyl)-2-azetidinone, (+)-2a. From 3.50 g (14.9 mmol) of imine and 3.05 g (22.3 mmol) of acetoxyacetyl chloride, 5.20 g (95%) of compound **(+)-2a** was obtained as a colorless solid after purification by flash chromatography (hexane/AcOEt 3/1). Colorless solid. Mp: 159-161 °C (hexanes/ethyl acetate). $[\alpha]_D = +89.9$ (c 1.0, CHCl₃). ¹H-NMR: δ 1.34 and 1.51 (s, each 3H), 2.18 (s, 3H), 3.65 (dd, 1H, *J* = 8.8, 6.6 Hz), 3.80 (s, 3H), 4.06 (dd, 1H, *J* = 8.8, 6.6 Hz), 4.35 (m, 2H), 6.02 (d, 1H, *J* = 5.1 Hz), 6.87 and 7.63 (dt, each 2H, *J* = 7.0, 2.2 Hz). ¹³C-NMR: δ 169.1, 161.8, 156.7, 130.7, 119.7, 114.0, 110.2, 76.5, 73.0, 66.3, 61.4, 55.4, 55.4, 26.5, 24.8, 20.5. IR (KBr, cm⁻¹): ν 1759, 1747. MS (EI), *m/z* : 337 (*M*⁺ + 1, 9), 307 (*M*⁺, 37), 149 (100). (Anal. Calcd for C₁₇H₂₁NO₆: C, 60.89; H, 6.31; N, 4.18. Found: C, 60.79; H, 6.48; N, 3.95).

(+)-(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-3-methoxy-1-(p-methoxyphenyl)-2-azetidinone, (+)-2b. From 3.50 g (14.9 mmol) of imine and 2.42 g (22.3 mmol) of methoxyacetyl chloride, 3.67 g (80%) of compound **(+)-2b** was obtained as a white solid after purification by flash chromatography (hexane/AcOEt 3/1). Colorless solid. Mp: 95-96 °C (hexanes/ethyl acetate). $[\alpha]_D = +81.1$ (c 1.0, CH₂Cl₂). ¹H-NMR: δ 1.26 and 1.46 (s, each 3H), 3.55 (s, 3H), 3.66 (dd, 1H, $J = 8.8$, 6.6 Hz), 3.72 (s, 3H), 4.11 (dd, 1H, $J = 8.8$, 5.5 Hz), 4.18 (dd, 1H, $J = 8.8$, 6.6 Hz), 4.31 (td, 1H, $J = 8.8$, 6.6 Hz), 4.48 (d, 1H, $J = 5.5$ Hz), 6.79 and 7.59 (dt, each 2H, $J = 7.0$, 2.2 Hz). ¹³C-NMR: δ 164.9, 156.4, 131.1, 119.5, 113.9, 109.7, 82.1, 67.0, 61.7, 59.4, 55.4, 26.7, 24.9, 13.7. IR (KBr, cm⁻¹): ν 1755. MS (EI), m/z : 308 (M⁺ + 1, 8), 307 (M⁺, 35), 149 (100). (Anal. Calcd for C₁₆H₂₁NO₅: C, 62.53; H, 6.89; N, 4.56. Found: C, 62.50; H, 6.95; N, 4.55).

(+)-(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-3-phenoxy-1-(2-propenyl)-2-azetidinone, (+)-2c. From 1.69 g (10.0 mmol) of imine and 2.56 g (15.0 mmol) of phenoxyacetyl chloride, 2.24 g (74%) of compound **(+)-2c** was obtained as a colorless solid after purification by flash chromatography (hexane/AcOEt 5/1). Colorless solid. Mp: 63-65 °C (hexanes/ethyl acetate). $[\alpha]_D = +100.9$ (c 1.1, CHCl₃). ¹H-NMR: δ 1.37 and 1.44 (s, each 3H), 3.38 (dd, 1H, $J = 8.8$, 6.6 Hz), 3.82 (m, 2H), 4.18 (m, 2H), 4.45 (m, 1H), 5.20 (d, 1H, $J = 5.2$ Hz), 5.75 (m, 1H), 7.02 (m, 3H), 7.30 (m, 2H). ¹³C-NMR: δ 165.6, 157.3, 131.2, 129.6, 129.5, 122.5, 118.9, 109.7, 79.9, 77.1, 66.9, 59.8, 44.0, 26.8. IR (KBr, cm⁻¹): ν 1760, 1600. MS (EI), m/z : 304 (M⁺ + 1, 11), 307 (M⁺, 37), 149 (100). (Anal. Calcd for C₁₇H₂₁NO₄: C, 67.31; H, 6.98; N, 4.62. Found: C, 67.65; H, 6.51; N, 4.33).

(+)-(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-3-methoxy-1-(2-propenyl)-2-azetidinone, (+)-2d From 4.0 g (23.6 mmol) of imine and 3.86 g (35.6 mmol) of methoxyacetyl chloride, 3.20 g (55%) of compound **(+)-2d** was obtained as a colorless solid after purification by flash chromatography (hexane/AcOEt 2/1). Colorless solid. Mp: 60-61 °C (hexanes/ethyl acetate). $[\alpha]_D = +49.4$ (c 1.2, CHCl₃). ¹H-NMR: δ 1.27 and 1.35 (s, each 3H), 3.46 (s, 3H), 3.65 (m, 3H), 4.06 (dd, 1H, $J = 8.8$, 6.6 Hz), 4.35 (dd, 1H, $J = 14.0$, 7.0 Hz), 4.37 (d, 1H, $J = 5.1$ Hz), 5.15 (m, 2H), 5.85 (m, 1H). ¹³C-NMR: δ 167.3, 131.5, 118.6, 109.6, 82.9, 77.2, 66.8, 59.8, 59.2, 43.7, 26.9, 25.2. IR (KBr, cm⁻¹): ν 1745. MS (EI), m/z : 241 (M⁺ + 1, 17), 307 (M⁺, 65), 149 (100). (Anal. Calcd for C₁₂H₁₉NO₄: C, 59.73; H, 7.94; N, 5.80. Found: C, 60.12; H, 7.59; N, 5.92).

(+)-(3R,4S)-3-Benzoyloxy-1-(3-butenyl)-4-[(S)-2,2-dimethyl-1,3-dioxolan-4-yl]-2-azetidinone, (+)-2e. From 2.70 g (14.8 mmol) of imine and 4.09 g (22.0 mmol) of (benzyloxy)acetyl chloride, 2.18 g (58%) of compound **(+)-2e** was obtained as a colorless oil after purification by flash chromatography (hexane/AcOEt 3/1). Colorless oil. $[\alpha]_D = +64.8$ (*c* 1.0, CH₂Cl₂). ¹H-NMR: δ 1.35 and 1.46 (s, each 3H), 2.37 (m, 2H), 3.31 and 3.55 (dd, each 1H, *J* = 14.0, 7.0 Hz), 3.64 (dd, 1H, *J* = 8.8, 5.9 Hz), 3.67 (dd, 1H, *J* = 8.8, 5.1 Hz), 4.16 (dd, 1H, *J* = 8.8, 6.6 Hz), 4.33 (td, 1H, *J* = 8.8, 6.6 Hz), 4.60 (d, 1H, *J* = 5.1 Hz), 4.64 and 4.92 (d, each 1H, *J* = 12.0 Hz), 5.06 (dd, 1H, *J* = 8.8, 1.5 Hz), 5.10 (dd, 1H, *J* = 15.8, 1.5 Hz), 5.77 (m, 1H), 7.32 (m, 5H). ¹³C-NMR: δ 167.6, 137.0, 135.1, 128.4, 128.0, 127.7, 116.9, 108.6, 80.2, 77.0, 72.8, 66.8, 60.3, 40.3, 31.8, 26.8, 25.1. IR (CHCl₃, cm⁻¹): ν 1747. MS (EI), *m/z* : 332 (*M*⁺ + 1, 5), 331 (*M*⁺, 10), 91 (100). (Anal. Calcd for C₁₉H₂₅NO₄: C, 68.86; H, 7.60; N, 4.23. Found: C, 68.85; H, 7.65; N, 4.22).

(+)-(3R,4S)-1-(3-Butenyl)-4-[(S)-2,2-dimethyl-1,3-dioxolan-4-yl]-3-methoxy-2-azetidinone, (+)-2f. From 4.22 g (23.0 mmol) of imine and 3.76 g (35.0 mmol) of methoxyacetyl chloride, 4.83 g (82%) of compound **(+)-2f** was obtained as a colorless solid after purification by flash chromatography (hexane/AcOEt 3/1). Colorless solid. Mp: 71-72 °C (hexanes/ethyl acetate). $[\alpha]_D = +66.9$ (*c* 1.5, CH₂Cl₂). ¹H-NMR (CDCl₃) δ : 1.28 and 1.38 (s, each 3H), 2.28 (m, 2H), 3.21 (dt, 1H, *J* = 13.5, 7.0 Hz), 3.41 (m, 1H), 3.46 (s, 3H), 3.56 (m, 2H), 4.06 (dd, 1H, *J* = 8.5, 6.5 Hz), 4.19 (td, 1H, *J* = 8.8, 6.6 Hz), 4.33 (d, 1H, *J* = 5.1 Hz), 5.02 (m, 2H), 5.70 (m, 1H). ¹³C-NMR (CDCl₃) δ : 167.7, 135.3, 117.0, 109.6, 82.7, 77.1, 66.9, 60.5, 59.2, 40.4, 31.9, 26.9, 25.2. IR (KBr, cm⁻¹) ν : 1745. MS (EI), *m/z* : 256 (*M*⁺ + 1, 7), 307 (*M*⁺, 43), 149 (100). (Anal. Calcd for C₁₃H₂₁NO₄: C, 61.16; H, 8.29; N, 5.49. Found: C, 61.14; H, 8.35; N, 5.52).

(+)-(3R,4S)-1-(3-Butynyl)-4-[(S)-2,2-dimethyl-1,3-dioxolan-4-yl]-3-methoxy-2-azetidinone, (+)-2g. From 4.50 g (25.0 mmol) of imine and 4.09 g (38.0 mmol) of methoxyacetyl chloride, 6.0 g (95%) of compound **(+)-2g** was obtained as a white solid after purification by flash chromatography (hexane/AcOEt 3/1). Mp: 73-74 °C (hexanes/ethyl acetate). $[\alpha]_D = +34.2$ (*c* 3.0, CH₂Cl₂). ¹H-NMR: δ 1.28 and 1.38 (s, each 3H), 1.93 (1H, t, *J* = 2.7 Hz), 2.46 (dt, 2H, *J* = 6.9, 2.7 Hz), 3.33 (ddd, 1H, *J* = 14.0, 13.5, 6.6 Hz), 3.47 (s, 3H), 3.51 (dd, 1H, *J* = 13.5, 7.0 Hz), 3.57 (dd, 1H, *J* = 8.5, 5.9 Hz), 3.68 (dd, 1H, *J* = 9.0, 5.1 Hz), 4.06 (dd, 1H, *J* = 8.5, 5.9 Hz), 4.20 (ddd, 1H, *J* = 9.0, 6.6, 5.6 Hz), 4.40 (d, 1H, *J* = 5.1 Hz). ¹³C-NMR: δ 167.5, 109.4, 82.7, 80.8, 76.8, 69.9, 66.6,

60.5, 59.0, 39.6, 26.7, 25.0, 17.5. IR (KBr, cm^{-1}): ν 3293, 1734. MS (EI), m/z : 254 ($\text{M}^+ + 1$, 11), 253 (M^+ , 43), 91 (100). (Anal. Calcd for $\text{C}_{13}\text{H}_{19}\text{NO}_4$: C, 61.64; H, 7.56; N, 5.53. Found: C, 61.70; H, 7.56; N, 5.53).

(+)-(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-3-methoxy-1-(4-pentynyl)-2-azetidinone, (+)-2h. From 4.85 g (25.0 mmol) of imine and 4.09 g (38.0 mmol) of methoxyacetyl chloride, 3.30 g (50%) of compound (+)-2h was obtained as a pale yellow oil after purification by flash chromatography (hexane/AcOEt 3/1). $[\alpha]_{\text{D}} = +73.9$ (c 2.5, CH_2Cl_2). $^1\text{H-NMR}$: δ 1.28 and 1.38 (s, each 3H), 1.80 (m, 2H), 1.91 (1H, t, $J = 2.7$ Hz), 2.15 (dd, 1H, $J = 7.0, 2.7$ Hz), 2.18 (ddd, 1H, $J = 7.0, 2.7, 1.5$ Hz), 3.32 (td, 1H, $J = 14.0, 7.0$ Hz), 3.46 (s, 3H), 3.48 (dd, 1H, $J = 14.0, 7.0$ Hz), 3.57 (dd, 1H, $J = 8.8, 3.0$ Hz), 3.60 (dd, 1H, $J = 8.8, 5.1$ Hz), 4.06 (dd, 1H, $J = 8.8, 6.6$ Hz), 4.19 (m, 1H), 4.35 (d, 1H, $J = 5.1$ Hz). $^{13}\text{C-NMR}$: δ 167.7, 109.5, 83.2, 82.7, 77.7, 68.9, 66.8, 60.6, 59.2, 40.6, 26.9, 26.4, 25.1, 16.3. IR (CHCl_3 , cm^{-1}): ν 3309, 1749. MS (EI), m/z : 268 ($\text{M}^+ + 1$, 28), 267 (M^+ , 100). (Anal. Calcd for $\text{C}_{14}\text{H}_{21}\text{NO}_4$: C, 62.90; H, 7.92; N, 5.24. Found: C, 62.80; H, 7.82; N, 5.34).

Synthesis of (+)-(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-3-hydroxy-1-(p-methoxyphenyl)-2-azetidinone, (+)-3. Sodium methoxide (836 mg, 15.47 mmol) was added in portions at room temperature to a solution of the acetoxyl- β -lactam (+)-2a (5.20 g, 15.47 mmol) in methanol (190 mL). The reaction was stirred for 20 min. and then water was added (20 mL). The methanol was removed under reduced pressure, the aqueous residue was extracted with ethyl acetate (4 x 50 mL) and the organic layer was dried (MgSO_4). The solvent was removed under reduced pressure, and 4.40 g (95%) of analytical pure compound was obtained. Colorless solid. Mp: 212-213 $^{\circ}\text{C}$ (hexanes/ethyl acetate). $[\alpha]_{\text{D}} = +107.3$ (c 0.8, CHCl_3). $^1\text{H-NMR}$: δ 1.29 and 1.39 (s, each 3H), 3.72 (s, 3H), 3.80 (dd, 1H, $J = 8.8, 6.6$ Hz), 4.22 (m, 2H), 4.40 (m, 2H), 4.93 (d, 1H, $J = 5.1$ Hz), 6.79 and 7.48 (dt, each 2H, $J = 7.0, 2.2$ Hz). $^{13}\text{C-NMR}$: δ 167.1, 156.7, 130.8, 119.7, 114.1, 119.9, 76.3, 75.1, 66.6, 61.4, 55.4, 26.4, 25.1. IR (KBr, cm^{-1}): ν 3338, 1716. MS (EI), m/z : 294 ($\text{M}^+ + 1$, 8), 293 (M^+ , 34), 149 (100). (Anal. Calcd for $\text{C}_{15}\text{H}_{19}\text{NO}_5$: C, 61.42; H, 6.53; N, 4.77. Found: C, 61.49; H, 6.44; N, 4.85).

Synthesis of (+)-(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-(p-methoxyphenyl)-3-(2-propenyloxy)-2-azetidinone, (+)-4. Tetrabutyl ammonium iodide (31.9 mg, 0.086 mmol), 50%

aqueous sodium hydroxide (100 mL) and allyl bromide (1.67 g, 13.82 mmol) were sequentially added at room temperature to a solution of the hydroxy- β -lactam (+)-**3** (2.54 g, 8.64 mmol) in dichloromethane (100 mL). The reaction was stirred for 20 h and then water was added (50 mL), before being partitioned between dichloromethane and water. The aqueous phase was extracted with dichloromethane (3 x 50 mL), the combined organic extracts were dried (MgSO₄) and concentrated under reduced pressure. Chromatography of the residue using hexane/AcOEt (7/3) as eluent gave 2.02 g (70%) of compound (+)-**4**. Colorless solid. Mp: 81-82 °C (hexanes/ethyl acetate). $[\alpha]_D^{25} = +121.1$ (*c* 1.0, CHCl₃). ¹H-NMR: δ 1.26 and 1.46 (s, each 3H), 3.67 (m, 1H), 3.71 (s, 3H), 4.12 (m, 2H), 4.20 (dd, 1H, *J* = 8.8, 6.6 Hz), 4.34 (m, 2H), 4.62 (d, 1H, *J* = 5.1 Hz), 5.20 (m, 2H), 5.90 (m, 1H), 6.78 and 7.59 (dt, each 2H, *J* = 7.0, 2.2 Hz). ¹³C-NMR: δ 165.0, 156.4, 133.3, 131.1, 119.5, 118.1, 113.9, 109.7, 80.2, 72.3, 67.0, 61.8, 55.4, 26.7, 24.9. IR (KBr, cm⁻¹): ν 1722. MS (EI), *m/z* : 334 (*M*⁺ + 1, 11), 333 (*M*⁺, 47), 149 (100). (Anal. Calcd for C₁₈H₂₃NO₅: C, 64.85; H, 6.95; N, 4.20. Found: C, 64.71; H, 7.02; N, 4.25).

Synthesis of (+)-(3*R*,4*S*)-3-(2-Carboxymethyl-1-ethenyloxy)-4-[(*S*)-2,2-dimethyl-1,3-dioxolan-4-yl]-1-(*p*-methoxyphenyl)-2-azetidinone, (+)-5**.** Triethylamine (344 mg, 3.40 mmol) and methyl propiolate (172 mg, 2.04 mmol) were sequentially added to a solution of the hydroxy- β -lactam (+)-**3** (500 mg, 1.70 mmol) in dichloromethane (10 mL) at 0 °C. The reaction was stirred for 2 h at 0 °C and then water (5 mL) was added. The mixture was diluted with dichloromethane (20 mL), before being partitioned between dichloromethane and water. The organic layer was dried (MgSO₄) and concentrated under reduced pressure. Chromatography of the residue using hexane/AcOEt (2/1) as eluent gave 464 mg (72%) of compound (+)-**5**. Colorless solid. Mp: 123-124 °C (hexanes/ethyl acetate). $[\alpha]_D^{25} = +138.3$ (*c* 0.5, CH₂Cl₂). ¹H-NMR: δ 1.28 and 1.37 (s, each 3H), 3.64 (s, 3H), 3.73 (s, 3H), 4.16 and 4.25 (dd, 1H, *J* = 8.8, 6.6 Hz), 4.27 (d, 1H, *J* = 5.1 Hz), 4.36 (m, 1H), 5.10 (d, 1H, *J* = 5.1 Hz), 5.54 (d, 1H, *J* = 12.5 Hz), 6.80 (dd, 2H, *J* = 7.0, 2.2 Hz), 7.50 (d, 1H, *J* = 12.5 Hz), 7.58 (dd, 2H, *J* = 7.0, 2.2 Hz). ¹³C-NMR: δ 167.1, 160.9, 159.6, 156.9, 137.1, 130.5, 119.8, 114.0, 110.3, 100.6, 80.7, 66.8, 61.3, 55.5, 51.4, 26.6, 24.8. IR (KBr, cm⁻¹): ν 1752, 1700. MS (EI), *m/z* : 378 (*M*⁺ + 1, 5), 377 (*M*⁺, 47), 149 (100). (Anal. Calcd for C₁₉H₂₃NO₇: C, 60.47; H, 6.14; N, 3.71. Found: C, 60.55; H, 5.95; N, 3.64).

General Procedure for the Synthesis of Compounds 6a-g and 16. To a solution of the corresponding acetonide β -lactam (10 mmol) in THF/water (1:1, 200 mL) was added solid *p*-TsOH·H₂O (12 mmol) in a single portion. The resulting clear solution was heated under reflux for 2 h. The reaction mixture was allowed to cool to room temperature, and then was neutralized with solid NaHCO₃. The mixture was extracted with ethyl acetate (3 x 40 mL), the organic layer was dried (MgSO₄) and the solvent was removed under reduced pressure. Further purification was not necessary. Spectroscopic and analytical data for some representative forms of **6** follow.

(+)-(3*R*,4*S*)-4-[(*S*)-1,2-dihydroxyethylen]-3-methoxy-1-(*p*-methoxyphenyl)-2-azetidinone, (+)-6a. From 2.30 g (7.47 mmol) of compound (+)-**2b**, 2.0 g (100%) of compound (+)-**6a** was obtained as a colorless oil. $[\alpha]_D = +118.9$ (*c* 1.3, CH₂Cl₂). ¹H-NMR: δ 2.49 and 3.01 (brs, each 1H), 3.10 and 3.59 (m, 1H), 3.60 (s, 3H), 3.71 (s, 3H), 4.07 (m, 1H), 4.33 (dd, 1H, *J* = 5.5, 4.4 Hz), 4.57 (d, 1H, *J* = 5.5 Hz), 6.78 and 7.37 (dd, each 2H, *J* = 7.0, 2.2 Hz). ¹³C-NMR: δ 165.0, 156.7, 130.8, 120.0, 114.2, 82.7, 71.5, 63.5, 59.8, 58.1, 55.5. IR (CHCl₃, cm⁻¹): ν 3404, 1728. MS (EI), *m/z* : 268 (*M*⁺ + 1, 11), 267 (*M*⁺, 64), 91 (100). (Anal. Calcd for C₁₃H₁₇NO₅: C, 58.42; H, 6.41; N, 5.24. Found: C, 58.40; H, 6.38; N, 5.28).

(+)-(3*R*,4*S*)-3-Benzoyloxy-1-(3-butenyl)-4-[(*S*)-1,2-dihydroxyethylen]-2-azetidinone, (+)-6c. From 1.35 g (4.08 mmol) of compound (+)-**2e**, 1.18 g (100%) of compound (+)-**6c** was obtained as a pale brown oil. $[\alpha]_D = +32.6$ (*c* 1.0, CH₂Cl₂). ¹H-NMR: δ 2.14 (br, 1H), 2.35 (m, 2H), 2.83 (br, 1H), 3.21 (dd, 1H, *J* = 14.0, 7.0 Hz), 3.71 (m, 4H), 4.00 (m, 1H), 4.67 (d, 1H, *J* = 5.1 Hz), 4.71 and 4.97 (d, each 1H, *J* = 11.7 Hz), 5.07 (dd, 1H, *J* = 8.5, 1.5 Hz), 5.07 (dd, 1H, *J* = 15.5, 1.5 Hz), 5.76 (m, 1H), 7.32 (m, 5H). IR (CHCl₃, cm⁻¹): ν 3410, 1737. MS (EI), *m/z* : 292 (*M*⁺ + 1, 4), 291 (*M*⁺, 7), 91 (100). (Anal. Calcd for C₁₆H₂₁NO₄: C, 65.96; H, 7.27; N, 4.81. Found: C, 66.01; H, 7.22; N, 4.78).

(+)-(3*R*,4*S*)-1-(3-Butynyl)-4-[(*S*)-1,2-dihydroxyethylen]-3-methoxy-2-azetidinone, (+)-6d. From 750 mg (2.96 mmol) of compound (+)-**2g**, 631 mg (100%) of compound (+)-**6d** was obtained as a colorless solid. Mp: 91-93 °C (hexanes/ethyl acetate). $[\alpha]_D = +69.8$ (*c* 2.5, CH₂Cl₂). ¹H-NMR: δ 1.96 (t, 1H, *J* = 2.7 Hz), 2.46 (ddt, 2H, *J* = 7.0, 2.7, 0.7 Hz), 2.66 and 3.12 (brs, each 1H), 3.29 (ddd, 1H, *J* = 13.5, 12.5, 6.4 Hz), 3.53 (s, 3H), 3.64 (m, 3H), 3.87 (dd, 1H, *J* = 10.0, 4.9 Hz), 3.92 (m, 1H), 4.46 (d, 1H, *J* = 4.9 Hz). ¹³C-NMR: δ 168.0, 83.0, 81.1, 71.3, 70.3, 63.9, 59.4, 58.8,

40.3, 17.7. IR (CHCl₃, cm⁻¹): ν 3416, 1739. MS (EI), m/z : 214 (M⁺ + 1, 15), 213 (M⁺, 27), 91 (100). (Anal. Calcd for C₁₀H₁₅NO₄: C, 56.39; H, 7.21; N, 6.41. Found: C, 56.33; H, 7.09; N, 6.57).

(+)-(3*R*,4*S*)-4-[(*S*)-1,2-Dihydroxyethylen]-3-methoxy-1-(4-pentynyl)-2-azetidinone, (+)-6e. From 1.0 g (3.75 mmol) of compound (+)-2h, 750 mg (88%) of compound (+)-6e was obtained as a colorless oil. $[\alpha]_D = +63.7$ (*c* 2.5, CH₂Cl₂). ¹H-NMR: δ 1.77 (m, 2H), 1.94 (t, 1H, *J* = 2.7 Hz), 2.15 and 2.18 (dd, each 1H, *J* = 7.0, 2.7 Hz), 2.30 and 3.05 (brs, each 1H), 3.22 (dt, 1H, *J* = 13.5, 7.0 Hz), 3.48 (dd, 1H, *J* = 13.5, 7.0 Hz), 3.53 (s, 3H), 3.62 (m, 2H), 3.74 (t, 1H, *J* = 4.9 Hz), 3.90 (m, 1H), 4.40 (d, 1H, *J* = 4.9 Hz). ¹³C-NMR: δ 168.0, 83.3, 83.1, 71.4, 69.3, 64.0, 59.6, 58.7, 41.2, 26.3, 16.3. IR (CHCl₃, cm⁻¹): ν 3415, 3292, 1740. MS (EI), m/z : 228 (M⁺ + 1, 5), 227 (M⁺, 11), 91 (100). (Anal. Calcd for C₁₁H₁₇NO₄: C, 58.14; H, 7.54; N, 6.16. Found: C, 58.06; H, 7.44; N, 6.08).

(+)-(3*R*,4*S*)-3-Allyloxy-1-(*p*-methoxyphenyl)-4-[(*S*)-1,2-dihydroxyethylen]-2-azetidin-one, (+)-6f. From 850 mg (2.54 mmol) of compound (+)-4, 746 mg (100%) of compound (+)-6f was obtained as a pale brown solid. Mp: 81-82 °C (hexanes/ethyl acetate). $[\alpha]_D = +112.0$ (*c* 1.0, CHCl₃). ¹H-NMR: δ 2.07 and 2.81 (br, each 1H), 3.48 (m, 1H), 3.72 (s, 3H), 4.08 (dd, 1H, *J* = 14.0, 7.0 Hz), 4.16 (d, 1H, *J* = 5.3 Hz), 4.19 (dd, 1H, *J* = 12.5, 6.2 Hz), 4.37 (m, 2H), 4.74 (d, 1H, *J* = 5.3 Hz), 4.71 and 4.97 (d, each 1H, *J* = 11.7 Hz), 5.27 (m, 2H), 5.88 (m, 1H), 6.80 and 7.33 (dd, each 1H, *J* = 9.0, 2.0 Hz). IR (CHCl₃, cm⁻¹): ν 3414, 1741. MS (EI), m/z : 294 (M⁺ + 1, 15), 291 (M⁺, 42), 91 (100). (Anal. Calcd for C₁₅H₁₉NO₅: C, 61.42; H, 6.53; N, 4.78. Found: C, 61.27; H, 6.72; N, 4.91).

(+)-(3*R*,4*S*)-3-(2-Carboxymethyl-1-ethenyloxy)-4-[(*S*)-1,2-dihydroxyethylen]-1-(*p*-methoxyphenyl)-2-azetidinone, (+)-6g. From 464 mg (1.23 mmol) of compound (+)-5, 412 mg (100%) of compound (+)-6g was obtained as a colorless solid. Mp: 126-127 °C (hexanes/ethyl acetate). $[\alpha]_D = +138.3$ (*c* 0.5, CH₂Cl₂). ¹H-NMR: δ 1.96 (brs, 1H), 2.38 (d, 1H, *J* = 4.0 Hz), 3.65 (m, 2H), 3.66 (s, 3H), 3.73 (s, 3H), 4.11 (m, 1H), 4.49 (dd, 1H, *J* = 8.8, 5.1 Hz), 5.15 (d, 1H, *J* = 5.5 Hz), 5.53 (d, 1H, *J* = 12.5 Hz), 6.81 and 7.40 (dd, each 2H, *J* = 7.0, 2.2 Hz), 7.54 (d, 1H, *J* = 12.5 Hz). IR (KBr, cm⁻¹): ν 3431, 3273, 1761, 1697. MS (EI), m/z : 338 (M⁺ + 1, 7), 267 (M⁺, 35), 91 (100). (Anal. Calcd for C₁₆H₁₉NO₇: C, 56.97; H, 5.68; N, 4.15. Found: C, 56.85; H, 5.78; N, 4.11).

(+)-(3*R*,4*S*)-4-[(*S*)-1,2-Dihydroxyethylen]-3-methoxy-1-(2-oxo-3-pentenyl)-2-azetidinone, (+)-16. From 350 mg (1.24 mmol) of compound (+)-E-14, 225 mg (75%) of compound (+)-16

were obtained as a pale brown oil. $[\alpha]_D = +50.0$ (c 1.0, CH_2Cl_2). $^1\text{H-NMR}$: δ 1.87 (dd, 3H, $J = 6.9$, 1.5 Hz), 2.41 (brs, 2H), 3.38 (m, 1H), 3.55 (s, 3H), 3.68 (m, 1H), 3.92 (m, 1H), 3.97 (m, 2H), 4.32 (m, 1H), 4.57 (d, 1H, $J = 4.8$ Hz), 6.07 (dq, 1H, $J = 15.9$, 1.7 Hz), 6.91 (qd, 1H, $J = 15.9$, 6.9 Hz). $^{13}\text{C-NMR}$: δ 194.3, 168.7, 145.7, 129.1, 83.8, 70.7, 64.3, 60.5, 59.6, 48.6, 18.7. IR (CHCl_3 , cm^{-1}) ν : 3420, 1740, 1670. MS (EI), m/z : 243 ($\text{M}^+ + 1$, 8), 213 (M^+ , 16), 91 (100). (Anal. Calcd for $\text{C}_{11}\text{H}_{17}\text{NO}_5$: C, 54.31; H, 7.04; N, 5.76. Found: C, 54.25; H, 7.00; N, 5.82).

General Procedure for the Synthesis of 4-oxoazetidine-2-carbaldehydes 1d-l, 10a-b and 24. Saturated aqueous sodium hydrogen carbonate (243 μL) was added to a solution of the corresponding diol (2.43 mmol) in dichloromethane (15 mL), maintaining the temperature below 25 $^\circ\text{C}$. Solid sodium periodate (4.86 mmol) was added over a 10 min period with vigorous stirring and the reaction was allowed to proceed for 2 h, while the temperature was maintained below 25 $^\circ\text{C}$. The solid was removed by filtration, the filtrate was dried (MgSO_4) and the solvent was removed under reduced pressure. The crude product was used for next step without any further purification. Spectroscopic and analytical data for some representative forms of **1** follow.

(+)-(3R, 4R)-4-Formyl-3-methoxy-1-(p-methoxyphenyl)-2-azetidinone, (+)-1d. From 200 mg (0.746 mmol) of compound (+)-**6a**, 175 mg (100%) of compound (+)-**1d** was obtained as a colorless oil. $[\alpha]_D = +104.4$ (c 1.2, CH_2Cl_2). $^1\text{H-NMR}$: δ 3.49 (s, 3H), 3.72 (s, 3H), 4.47 (dd, 1H, $J = 5.1$, 3.9 Hz), 4.82 (d, 1H, $J = 5.1$ Hz), 6.81 and 7.19 (dd, each 2H, $J = 7.0$, 2.2 Hz), 9.70 (d, 1H, $J = 3.8$ Hz). $^{13}\text{C-NMR}$: δ 199.1, 162.8, 157.0, 130.5, 118.1, 114.6, 85.1, 63.2, 59.4, 55.5. IR (CHCl_3 , cm^{-1}): ν 1725, 1717. MS (EI), m/z : 236 ($\text{M}^+ + 1$, 7), 235 (M^+ , 19), 91 (100). (Anal. Calcd for $\text{C}_{12}\text{H}_{13}\text{NO}_4$: C, 61.27; H, 5.57; N, 5.95. Found: C, 61.29; H, 5.50; N, 5.98).

(+)-(3R, 4R)-4-Formyl-3-phenoxy-1-(2-propenyl)-2-azetidinone, (+)-1e. From 1.46 g (2.43 mmol) of compound (+)-**6b**, 1.13 g (100%) of compound (+)-**1e** was obtained as a colorless oil. $[\alpha]_D = +59.4$ (c 1.0, CHCl_3). $^1\text{H-NMR}$: δ 3.87 and 3.97 (dd, each 1H, $J = 15.0$, 6.5 Hz), 4.30 (dd, 1H, $J = 5.1$, 2.4 Hz), 5.16 (m, 2H), 5.36 (d, 1H, $J = 5.1$ Hz), 5.68 (m, 1H), 5.82 (m, 1H), 6.91 (m, 2H), 7.20 (m, 3H), 9.59 (d, 1H, $J = 3.0$ Hz). $^{13}\text{C-NMR}$: δ 197.2, 164.3, 156.7, 130.3, 129.6, 122.9, 120.4, 115.4, 82.0, 63.2, 44.4. IR (CHCl_3 , cm^{-1}): ν 1745, 1728. MS (EI), m/z : 232 ($\text{M}^+ + 1$, 5), 261 (M^+ , 11), 91 (100). (Anal. Calcd for $\text{C}_{13}\text{H}_{13}\text{NO}_3$: C, 67.52; H, 5.67; N, 6.06. Found: C, 67.87; H, 5.35; N, 6.38).

(+)-(3R,4R)-2-Benzoyloxy-1-(3-butenyl)-4-formyl-2-azetidinone, (+)-1f. From 600 mg (2.06 mmol) of compound (+)-6c, 530 mg (100%) of compound (+)-1f was obtained as a pale brown oil. $[\alpha]_D = +29.2$ (c 3.0, CH₂Cl₂). ¹H-NMR: δ 2.22 (m, 2H), 3.28 and 3.46 (dt, each 1H, $J = 14.5, 7.0$ Hz), 4.09 (dd, 1H, $J = 5.1, 3.0$ Hz), 4.55 and 4.70 (d, each 1H, $J = 11.7$ Hz), 4.84 (d, 1H, $J = 5.1$ Hz), 4.98 (q, 1H, $J = 1.5$ Hz), 5.06 (dq, 1H, $J = 7.5, 1.7$ Hz), 5.65 (m, 1H), 7.27 (m, 5H), 9.52 (d, 1H, $J = 3.0$ Hz). ¹³C-NMR: δ 198.9, 166.5, 135.9, 134.3, 128.6, 128.4, 128.2, 117.7, 83.4, 73.3, 64.0, 40.8, 31.9. IR (CHCl₃, cm⁻¹): ν 1745, 1725. MS (EI), m/z : 260 ($M^+ + 1, 4$), 259 ($M^+, 10$), 91 (100). (Anal. Calcd for C₁₅H₁₇NO₃: C, 69.48; H, 6.61; N, 5.40. Found: C, 69.58; H, 6.52; N, 5.29).

(+)-(3R,4R)-1-(3-Butynyl)-4-formyl-3-methoxy-2-azetidinone, (+)-1g. From 740 mg (3.47 mmol) of compound (+)-6d, 629 mg (100%) of compound (+)-1g was obtained as a colorless oil. $[\alpha]_D = +123.5$ (c 3.0, CH₂Cl₂). ¹H-NMR: δ 1.97 (t, 1H, $J = 2.7$ Hz), 2.43 (ddt, 2H, $J = 7.0, 2.7, 0.7$ Hz), 3.44 (s, 3H), 3.47 (m, 2H), 4.35 (dd, 1H, $J = 5.1, 2.6$ Hz), 4.77 (d, 1H, $J = 5.1$ Hz), 9.69 (d, 1H, $J = 2.6$ Hz). ¹³C-NMR: δ 198.6, 166.3, 86.1, 80.6, 70.9, 64.5, 59.1, 40.3, 18.2. IR (CHCl₃, cm⁻¹): ν 3301, 1748, 1724. MS (EI), m/z : 182 ($M^+ + 1, 3$), 181 ($M^+, 11$), 91 (100). (Anal. Calcd for C₉H₁₁NO₃: C, 59.51; H, 6.05; N, 7.81. Found: C, 59.66; H, 6.12; N, 7.73).

(+)-(3R, 4R)-4-Formyl-3-methoxy-1-(4-pentynyl)-2-azetidinone, (+)-1h. From 700 mg (3.08 mmol) of compound (+)-6e, 490 mg (82%) of compound (+)-1h was obtained as a colorless oil. $[\alpha]_D = +63.5$ (c 2.5, CH₂Cl₂). ¹H-NMR: δ 1.73 (m, 2H), 1.94 (t, 1H, $J = 2.7$ Hz), 2.21 (m, 2H), 3.33 (dt, 1H, $J = 14.0, 7.0$ Hz), 3.44 (s, 3H), 3.48 (dd, 1H, $J = 14.0, 7.0$ Hz), 4.19 (dd, 1H, $J = 5.1, 2.7$ Hz), 4.72 (d, 1H, $J = 5.1$ Hz), 9.66 (d, 1H, $J = 2.7$ Hz). ¹³C-NMR: δ 198.5, 166.2, 85.7, 82.3, 69.4, 64.0, 59.1, 41.0, 26.3, 16.0. IR (CHCl₃, cm⁻¹): ν 3309, 1750, 1724. MS (EI), m/z : 196 ($M^+ + 1, 28$), 195 ($M^+, 100$). (Anal. Calcd for C₁₀H₁₃NO₃: C, 61.53; H, 6.71; N, 7.17. Found: C, 61.63; H, 6.56; N, 7.09).

(+)-(3R, 4R)-4-Formyl-3-allyloxy-1-(p-methoxyphenyl)-2-azetidinone, (+)-1i. From 715 mg (2.43 mmol) of compound (+)-6f, 555 mg (87%) of compound (+)-1i was obtained as a colorless solid. Mp: 96-98 °C (hexanes/ethyl acetate). $[\alpha]_D = +160.4$ (c 2.0, CHCl₃). ¹H-NMR: δ 3.71 (s, 3H), 4.19 and 4.29 (dd, each 1H, $J = 12.5, 6.0$ Hz), 4.45 (dd, 1H, $J = 5.1, 3.9$ Hz), 4.94 (d, 1H, $J = 5.1$ Hz), 5.22 (m, 2H), 5.82 (m, 1H), 6.79 and 7.19 (dd, each 2H, $J = 7.0, 2.2$ Hz), 9.70 (d, 1H, $J = 3.6$ Hz). ¹³C-NMR: δ 199.2, 163.0, 156.9, 132.7, 130.5, 119.1, 118.3, 114.6, 82.9, 72.6,

63.3, 55.5. IR (KBr, cm^{-1}): ν 1743, 1720. MS (EI), m/z : 262 ($\text{M}^+ + 1$, 5), 261 (M^+ , 17), 91 (100). (Anal. Calcd for $\text{C}_{14}\text{H}_{15}\text{NO}_4$: C, 64.36; H, 5.79; N, 5.36. Found: C, 64.49; H, 5.88; N, 5.45).

(+)-(3R, 4R)-3-(2-Carboxymethyl-1-ethenyloxy)-4-formyl-1-(p-methoxyphenyl)-2-azetidinone, (+)-1j. From 412 mg (1.22 mmol) of compound (+)-6g, 370 mg (100%) of compound (+)-1j was obtained as a pale brown oil. $[\alpha]_{\text{D}} = +35.6$ (c 2.0, CH_2Cl_2). $^1\text{H-NMR}$: δ 3.63 (s, 3H), 3.68 (s, 3H), 4.67 (dd, 1H, $J = 5.1, 3.0$ Hz), 5.35 (d, 1H, $J = 5.1$ Hz), 5.45 (d, 1H, $J = 12.5$ Hz), 6.79 and 7.17 (dd, each 2H, $J = 7.0, 2.0$ Hz), 7.44 (d, 1H, $J = 12.5$ Hz), 9.67 (d, 1H, $J = 3.0$ Hz). $^{13}\text{C-NMR}$: δ 196.3, 166.8, 159.4, 159.1, 157.3, 137.6, 129.9, 118.3, 114.7, 100.6, 81.8, 62.4, 55.5, 51.5. IR (CHCl_3 , cm^{-1}): ν 1761, 1740, 1725. MS (EI), m/z : 306 ($\text{M}^+ + 1$, 3), 305 (M^+ , 9), 91 (100). (Anal. Calcd for $\text{C}_{15}\text{H}_{15}\text{NO}_6$: C, 59.02; H, 4.95; N, 4.59. Found: C, 59.10; H, 4.83; N, 4.51).

(+)-(3R,4R)-4-Formyl-3-methoxy-1-(2-oxo-3-pentenyl)-2-azetidinone, (+)-1k. From 193 mg (0.794 mmol) of compound (+)-16, 103 mg (62%) of compound (+)-1k was obtained as a colorless oil. $[\alpha]_{\text{D}} = +63.2$ (c 1.0, CH_2Cl_2). $^1\text{H-NMR}$: δ 1.87 (dd, 3H, $J = 6.9, 1.7$ Hz), 3.47 (s, 3H), 4.26 and 4.47 (d, each 1H, $J = 18.5$ Hz), 4.48 (dd, 1H, $J = 5.1, 2.0$ Hz), 4.87 (d, 1H, $J = 5.1$ Hz), 6.04 (dq, 1H, $J = 15.9, 1.7$ Hz), 6.88 (qd, 1H, $J = 15.9, 6.9$ Hz), 9.66 (d, 1H, $J = 2.0$ Hz). IR (CHCl_3 , cm^{-1}): ν 1745, 1725, 1675. MS (EI), m/z : 212 ($\text{M}^+ + 1$, 7), 211 (M^+ , 19), 91 (100). (Anal. Calcd for $\text{C}_{10}\text{H}_{13}\text{NO}_4$: C, 56.87; H, 6.20; N, 6.63. Found: C, 56.90; H, 6.23; N, 6.59).

(+)-(3R, 4R)-4-Formyl-3-methoxy-1-(2,4-pentadienyl)-2-azetidinone, (+)-1l. From 160 mg (0.705 mmol) of the corresponding diol, 135 mg (100%) of compound (+)-1l was obtained as a pale brown oil. $[\alpha]_{\text{D}} = +63.1$ (c 0.4, CH_2Cl_2). $^1\text{H-NMR}$: δ 3.44 (s, 3H), 3.95 (dd, 1H, $J = 13.2, 7.0$ Hz), 4.09 (m, 2H), 4.71 (d, 1H, $J = 5.1$ Hz), 5.09 (d, 1H, $J = 9.2$ Hz), 5.17 (d, 1H, $J = 16.2$ Hz), 5.50 (m, 1H), 6.11 (dd, 1H, $J = 14.5, 10.0$ Hz), 6.34 (dt, 1H, $J = 16.5, 10.0$ Hz), 9.60 (d, 1H, $J = 3.3$ Hz). IR (CHCl_3 , cm^{-1}): ν 1730, 1715. MS (EI), m/z : 196 ($\text{M}^+ + 1$, 3), 195 (M^+ , 11), 91 (100). (Anal. Calcd for $\text{C}_{10}\text{H}_{13}\text{NO}_3$: C, 61.53; H, 6.71; N, 7.17. Found: C, 61.51; H, 6.65; N, 7.20).

(+)-(3R, 4R)-4-Formyl-1-(3,5-hexadienyl)-3-methoxy-2-azetidinone, (+)-24. From 113 mg (0.469 mmol) of the corresponding diol, 96 mg (98%) of compound (+)-24 was obtained as a colorless oil. $[\alpha]_{\text{D}} = +38.5$ (c 1.0, CH_2Cl_2). $^1\text{H-NMR}$: δ 2.31 (m, 2H), 3.31 (td, 2H, $J = 13.5, 7.0$ Hz), 3.43 (s, 3H), 4.12 (dd, 1H, $J = 5.1, 2.9$ Hz), 4.69 (d, 1H, $J = 5.1$ Hz), 5.01 (dt, 1H, $J = 16.8, 0.7$ Hz), 5.06 (ddd, 1H, $J = 23.9, 1.7, 0.5$ Hz), 5.51 (m, 1H), 6.04 (ddt, 1H, $J = 15.0, 10.2, 1.2$ Hz), 6.22

(td, 1H, $J = 16.5, 10.2$ Hz), 9.62 (d, 1H, $J = 3.0$ Hz). IR (CHCl₃, cm⁻¹): ν 1735, 1717. MS (EI), m/z : 210 ($M^+ + 1$, 3), 195 (M^+ , 9), 91 (100). (Anal. Calcd for C₁₁H₁₅NO₃: C, 63.14; H, 7.23; N, 6.69. Found: C, 63.99; H, 7.25; N, 6.71).

Preparation of Aldehydes 10a-b. Solid trimethylamine *N*-oxide dihydrate (25.8 mmol) and a solution of osmium tetroxide (32.8 mg, 0.129 mmol) in isopropanol (1.6 mL) were sequentially added at room temperature to a solution of the corresponding 1-alkenyl 2-azetidinone (12.9 mmol) in acetone/H₂O (8:1, 170 mL). The reaction was allowed to proceed for 16 h. The reaction was cooled at 0 °C and 40% aqueous sodium hydrogen sulfite (140 mL) was added. The reaction was extracted with ethyl acetate (4 x 50 mL), the organic extracts were washed with water (10 mL), the organic phase was dried (MgSO₄) and the solvent was removed under reduced pressure. The crude diol (11.6 mmol) was dissolved in dichloromethane (15 mL) and saturated aqueous sodium hydrogen carbonate (1.16 mL) was added to this solution, maintaining the temperature below 25 °C. Solid sodium periodate (23.2 mmol) was added over a 10 min period with vigorous stirring and the reaction was allowed to proceed for 2 h, while the temperature was maintained below 25 °C. The solid was removed by filtration, the filtrate was dried (MgSO₄) and the solvent was removed under reduced pressure. The crude product was used for next step without any further purification.

(+)-(3*R*,4*S*)-4-[(*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-(2-formylmethylen)-3-methoxy-2-azetidinone, (+)-10a. From 3.11 g (12.9 mmol) of the 1-alkenyl 2-azetidinone (+)-2d, 2.56 g (82%) of compound (+)-10a was obtained as a pale brown oil. $[\alpha]_D = +140.2$ (c 1.3, CH₂Cl₂). ¹H-NMR: δ 1.18 and 1.30 (s, each 3H), 3.49 (s, 3H), 3.58 (dd, 1H, $J = 8.8, 5.5$ Hz), 3.76 (dd, 1H, $J = 9.2, 5.1$ Hz), 4.04 (dd, 1H, $J = 8.8, 6.6$ Hz), 4.13 and 4.14 (dd, each 1H, $J = 14.0, 7.0$ Hz), 4.25 (m, 1H), 4.52 (d, 1H, $J = 5.1$ Hz), 9.52 (s, 1H). ¹³C-NMR: δ 195.5, 167.9, 109.6, 83.3, 76.6, 66.6, 61.0, 59.2, 50.9, 26.8, 25.1. IR (CHCl₃, cm⁻¹): ν 1745, 1720. MS (EI), m/z : 244 ($M^+ + 1$, 8), 243 (M^+ , 20), 149 (100). (Anal. Calcd for C₁₁H₁₇NO₅: C, 54.31; H, 7.04; N, 5.76. Found: C, 54.35; H, 7.00; N, 5.78).

(+)-(3*R*,4*S*)-4-[(*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-(2-formylethylen)-3-methoxy-2-azetidinone, (+)-10b. From 1.0 g (3.92 mmol) of the 1-alkenyl 2-azetidinone (+)-2f, 835 mg (83%) of compound (+)-10b was obtained as a colorless oil. $[\alpha]_D = +77.5$ (c 2.2, CH₂Cl₂). ¹H-NMR: δ 1.28 and 1.38 (s, each 3H), 2.75 and 2.82 (dt, each 1H, $J = 6.9, 1.5$ Hz), 3.45 (s, 3H), 3.57 (m, 4H),

4.06 (dd, 1H, $J = 8.5, 6.6$ Hz), 4.18 (td, 1H, $J = 8.5, 6.6$ Hz), 4.34 (d, 1H, $J = 5.1$ Hz), 9.73 (s, 1H). ^{13}C -NMR: δ 199.7, 167.4, 109.4, 82.5, 76.6, 66.5, 60.8, 58.9, 41.5, 35.0, 26.6, 24.9. IR (CHCl_3 , cm^{-1}): ν 1738, 1715. MS (EI), m/z : 258 ($\text{M}^+ + 1$, 5), 257 (M^+ , 15), 149 (100). (Anal. Calcd for $\text{C}_{12}\text{H}_{19}\text{NO}_5$: C, 56.02; H, 7.44; N, 5.44. Found: C, 55.98; H, 7.45; N, 5.50).

Spectroscopic and analytical data for some representative forms of **7** follow.

(3R,4S)-4-[(R)-1-Hydroxy-3-butenyl]-3-phenoxy-1-(2-propenyl)-2-azetidinone, (+)-7e.

From 231 mg (1 mmol) of compound (+)-**1e**, 156 mg (57%) of compound (+)-**7e** was obtained as a yellow oil. $[\alpha]_{\text{D}} = +140.9$ (c 1.0, CH_2Cl_2). ^1H -NMR: δ 2.25 and 2.47 (m, each 1H), 2.34 (d, 1H, $J = 3.8$ Hz), 3.92 (m, 2H), 4.09 (m, 1H), 4.22 (ddt, 1H, $J = 15.4, 5.1, 1.5$ Hz), 5.24 (m, 5H), 5.86 (m, 2H), 7.08 (m, 3H), 7.32 (m, 2H). ^{13}C -NMR: δ 166.1, 157.4, 133.8, 131.9, 129.7, 122.7, 120.7, 118.7, 115.9, 80.3, 70.2, 60.4, 44.5, 38.7. IR (CHCl_3 , cm^{-1}): ν 3280, 1757. MS (EI), m/z : 274 ($\text{M}^+ + 1$, 4), 273 (M^+ , 10), 149 (100). (Anal. Calcd for $\text{C}_{16}\text{H}_{19}\text{NO}_3$: C, 70.3; H, 7.01; N, 5.12. Found: C, 70.35; H, 6.96; N, 5.10).

(3R,4S)-4-[(R)-1-Hydroxy-3-butenyl]-3-methoxy-1-(4-pentynyl)-2-azetidinone, (+)-7h.

From 195 mg (1 mmol) of compound (+)-**1h**, 168 mg (71%) of compound (+)-**7h** was obtained as a colorless oil. $[\alpha]_{\text{D}} = +68.0$ (c 2.5, CH_2Cl_2). ^1H -NMR: δ 1.84 (m, 2H), 1.96 (t, 1H, $J = 2.7$ Hz), 2.22 (m, 2H), 2.34 (m, 2H), 2.51 (d, 1H, $J = 3.2$ Hz), 3.29 (dt, 1H, $J = 14.0, 7.0$ Hz), 3.54 (dd, 1H, $J = 14.0, 7.0$ Hz), 3.57 (s, 3H), 3.69 (dd, 1H, $J = 4.9, 4.6$ Hz), 3.88 (m, 1H), 4.42 (d, 1H, $J = 4.9$ Hz), 5.12 and 5.19 (m, each 1H), 5.83 (m, 1H). ^{13}C -NMR: δ 167.8, 134.1, 118.5, 83.2, 83.1, 70.0, 69.2, 60.4, 59.5, 41.2, 38.8, 26.4, 16.3. IR (CHCl_3 , cm^{-1}): ν 3440, 3308, 1745. MS (EI), m/z : 238 ($\text{M}^+ + 1$, 29), 237 (M^+ , 100). (Anal. Calcd for $\text{C}_{13}\text{H}_{19}\text{NO}_3$: C, 65.80; H, 8.07; N, 5.90. Found: C, 65.65; H, 7.95; N, 6.01).

(3R,4S)-3-(2-Carboxymethyl-1-ethenyloxy)-4-[(R)-1-hydroxy-3-butenyl]-1-(p-methoxyphenyl)-2-azetidinone, (+)-7j. From 306 mg (1 mmol) of compound (+)-**1j**, 192 mg (55%) of compound (+)-**7j** was obtained as a yellow oil. $[\alpha]_{\text{D}} = +183.4$ (c 1.0, CH_2Cl_2). ^1H -NMR: δ 2.13 (d, 1H, $J = 4.0$ Hz), 2.26 and 2.40 (m, each 1H), 3.74 (s, 3H), 3.81 (s, 3H), 4.11 (m, 2H), 4.40 (dd, 1H, $J = 6.2, 5.5$ Hz), 5.20 (m, 2H), 5.60 (d, 1H, $J = 12.4$ Hz), 5.84 (m, 1H), 6.88 and 7.48 (dd, each 2H, $J = 7.0, 2.2$ Hz, ArH), 7.61 (d, 1H, $J = 12.4$ Hz). ^{13}C -NMR: δ 167.2, 161.6, 159.9, 157.0, 133.5, 130.3, 120.4, 119.0, 114.2, 100.4, 80.8, 70.4, 60.5, 55.5, 51.4, 38.5. IR (CHCl_3 , cm^{-1}): ν 3350,

1757, 1713. MS (EI), m/z : 348 ($M^+ + 1$, 9), 347 (M^+ , 39), 149 (100). (Anal. Calcd for $C_{18}H_{21}NO_6$: C, 62.24; H, 6.09; N, 4.03. Found: C, 62.20; H, 6.10; N, 4.08).

(3R,4S)-4-[(R)-1-Hydroxy-3-butenyl]-3-methoxy-1-(2,4-pentadienyl)-2-azetidinone, (+)-7l. From 195 mg (1 mmol) of compound (+)-1l, 175 mg (74%) of compound (+)-7l was obtained as a colorless oil. $[\alpha]_D^{25} = +26.6$ (c 1.2, CH_2Cl_2). 1H -NMR: δ 2.29 (m, 2H), 2.45 (d, 1H, $J = 3.3$ Hz), 3.58 (s, 3H), 3.67 (dd, 1H, $J = 7.5, 5.0$ Hz), 3.78 (dd, 1H, $J = 16.0, 7.5$ Hz), 3.86 (m, 1H), 4.19 (dd, 1H, $J = 16.0, 5.8$ Hz), 4.44 (d, 1H, $J = 5.0$ Hz), 5.15 (m, 4H), 5.61 (m, 1H), 5.80 (m, 1H), 6.19 (dd, 1H, $J = 14.7, 10.3$ Hz), 6.31 (td, 1H, $J = 16.2, 10.3$ Hz). ^{13}C -NMR: δ 167.4, 135.8, 134.5, 134.1, 127.0, 118.3, 118.1, 83.3, 69.9, 60.0, 59.4, 43.2, 38.6. IR ($CHCl_3$, cm^{-1}): ν 3380, 1740. MS (EI), m/z : 238 ($M^+ + 1$, 3), 237 (M^+ , 11), 87 (100). (Anal. Calcd for $C_{13}H_{19}NO_3$: C, 65.80; H, 8.07; N, 5.90. Found: C, 64.77; H, 8.02; N, 5.93).

Preparation of Homoallylic Alcohols 11a-b.

From 804 mg (3.31 mmol) of the aldehyde (+)-10a and 1.31 g (3.97 mmol) of allyltributyltin, after flash chromatography eluting with ethyl acetate/hexane (2:1), 245 mg (26%) of the less polar compound (+)-11b and 320 mg (34%) of the more polar compound (+)-11a were obtained.

(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[(S)-2-hydroxy-4-pentenyl]-3-methoxy-2-azetidinone, (+)-11a. White solid. Mp: 83-84 °C (hexanes/ethyl acetate). $[\alpha]_D^{25} = +88.1$ (c 1.0, CH_2Cl_2). 1H -NMR: δ 1.36 and 1.46 (s, each 3H), 2.29 (m, 2H), 3.34 (dd, 1H, $J = 14.3, 7.4$ Hz), 3.45 (dd, 1H, $J = 14.3, 3.0$ Hz), 3.55 (s, 3H), 3.65 (dd, 1H, $J = 8.8, 6.2$ Hz), 3.72 (m, 2H), 3.93 (m, 1H), 4.16 (dd, 1H, $J = 8.8, 6.6$ Hz), 4.31 (dt, 1H, $J = 9.2, 6.2$ Hz), 4.48 (d, 1H, $J = 5.1$ Hz), 5.12 (dd, 1H, $J = 3.0, 1.8$ Hz), 5.16 (ddd, 1H, $J = 8.1, 3.0, 1.5$ Hz), 5.86 (m, 1H). ^{13}C -NMR: δ 168.5, 134.0, 117.9, 109.8, 82.4, 77.0, 69.0, 66.8, 61.4, 59.2, 49.0, 39.3, 26.8, 25.1. IR (KBr, cm^{-1}): ν 3340, 1745. MS (EI), m/z : 286 ($M^+ + 1$, 1), 285 (M^+ , 3), 100 (100). (Anal. Calcd for $C_{14}H_{23}NO_5$: C, 58.93; H, 8.12; N, 4.91. Found: C, 58.97; H, 8.15; N, 4.89).

(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[(R)-2-hydroxy-4-pentenyl]-3-methoxy-2-azetidinone, (+)-11b. White solid. Mp: 57-58 °C (hexanes/ethyl acetate). $[\alpha]_D^{25} = +53.9$ (c 1.6, CH_2Cl_2). 1H -NMR: δ 1.36 and 1.45 (s, each 3H), 2.27 and 2.29 (dd, each 1H, $J = 12.0, 1.0$ Hz), 3.29 (dd, 1H, $J = 14.3, 7.7$ Hz), 3.50 (dd, 1H, $J = 14.3, 2.6$ Hz), 3.55 (s, 3H), 3.65 (dd, 1H, $J = 8.8, 6.2$ Hz), 3.72 (m, 2H), 3.96 (m, 1H), 4.15 (dd, 1H, $J = 8.8, 6.6$ Hz), 4.31 (dt, 1H, $J = 9.2, 6.2$ Hz),

4.47 (d, 1H, $J = 5.1$ Hz), 5.11 (s, 1H), 5.16 (dd, 1H, $J = 6.6, 1.5$ Hz), 5.86 (m, 1H). ^{13}C -NMR: δ 168.6, 134.2, 117.9, 109.9, 82.4, 77.1, 69.8, 66.8, 61.8, 59.3, 49.4, 39.6, 26.8, 25.2. IR (KBr, cm^{-1}): ν 3335, 1745. MS (EI), m/z : 286 ($\text{M}^+ + 1, 2$), 285 ($\text{M}^+, 5$), 100 (100). (Anal. Calcd for $\text{C}_{14}\text{H}_{23}\text{NO}_5$: C, 58.93; H, 8.12; N, 4.91. Found: C, 58.88; H, 8.14; N, 4.93).

(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[(RS)-3-hydroxy-5-hexenyl]-3-methoxy-2-azetidinone, (+)-13. From 780 mg (3.04 mmol) of the aldehyde (+)-10b, and 1.21 g (3.64 g) of allyltrimethylsilane, 480 mg (53%) of compound (+)-13 was obtained as a colorless oil. $[\alpha]_{\text{D}} = +63.4$ (c 2.5, CH_2Cl_2). ^1H -NMR: δ 1.28 and 1.38 (s, each 3H), 1.52 (m, 1H), 1.79 (m, 2H), 2.18 (dt, 2H, $J = 7.0, 1.0$ Hz), 2.91 (d, 0.4H, $J = 4.3$ Hz), 2.99 (d, 0.6H, $J = 4.3$ Hz), 3.36 (m, 1H), 3.46 (s, 3H), 3.58 (m, 3H), 4.09 (dd, 1H, $J = 8.5, 5.4$ Hz), 4.26 (m, 1H), 4.37 (dd, 1H, $J = 5.0, 4.0$ Hz), 5.00 (s, 1H), 5.07 (m, 1H), 5.78 (m, 1H). ^{13}C -NMR: δ 24.9 (M + m), 26.6 (M), 26.7 (m), 34.4 (m), 35.0 (M), 38.0 (M), 38.2 (m), 41.4 (m), 41.6 (M), 59.0 (M + m), 60.4 (m), 61.4 (M), 66.6 (M + m), 67.6 (m), 67.9 (M), 76.7 (M + m), 82.4 (M), 82.5 (m), 109.4 (M), 109.6 (m), 117.4 (M + m), 134.6 (M + m), 168.1 (m), 168.3 (M). IR (CHCl_3 , cm^{-1}): ν 3330, 1746. MS (EI), m/z : 300 ($\text{M}^+ + 1, 1$), 299 ($\text{M}^+, 4$), 100 (100). (Anal. Calcd for $\text{C}_{15}\text{H}_{25}\text{NO}_5$: C, 60.18; H, 8.42; N, 4.68. Found: C, 60.25; H, 8.37; N, 4.64).

Spectroscopic and analytical data for some representative forms of 8, 9 and 12 follow.

(R)-O-Acetylmandelate of (3R,4S)-4-[(R)-1-hydroxy-3-butenyl]-1-(p-methoxyphenyl)-3-(2-propenyloxy)-2-azetidinone, (+)-8i. From 18 mg (0.059 mmol) of compound (+)-7i, 22 mg (77%) of compound (+)-8i was obtained as a colorless oil. $[\alpha]_{\text{D}} = +25.3$ (c 2.1, CH_2Cl_2). ^1H -NMR: δ 2.09 (s, 3H), 2.50 (t, 2H, $J = 6.5$ Hz), 3.72 (s, 3H), 3.93 (ddt, 1H, $J = 12.9, 5.9, 1.5$ Hz), 4.02 (ddt, 1H, $J = 12.9, 5.2, 1.5$ Hz), 4.28 (t, 1H, $J = 5.5$ Hz), 4.54 (d, 1H, $J = 5.5$ Hz), 5.07 (m, 2H), 5.19 (ddd, 2H, $J = 19.5, 3.7, 3.0$ Hz), 5.39 (q, 1H, $J = 5.9$ Hz), 5.70 (s, 1H), 5.74 (m, 2H), 6.71 (dt, 2H, $J = 8.8, 2.5$ Hz), 7.20 (m, 7H). ^{13}C -NMR: δ 170.2, 168.2, 164.9, 156.6, 133.3, 133.0, 132.4, 130.3, 129.2, 128.7, 127.7, 119.6, 118.8, 118.0, 114.2, 80.3, 74.6, 72.9, 72.2, 57.1, 55.4, 35.4, 20.7. IR (CHCl_3 , cm^{-1}): ν 1748, 1645. MS (EI), m/z : 480 ($\text{M}^+ + 1, 30$), 479 ($\text{M}^+, 100$). (Anal. Calcd for $\text{C}_{27}\text{H}_{29}\text{NO}_7$: C, 67.63; H, 6.10; N, 2.92. Found: C, 67.69; H, 6.21; N, 2.80).

(S)-O-Acetylmandelate of (3R,4S)-4-[(R)-1-hydroxy-3-butenyl]-1-(p-methoxyphenyl)-3-(2-propenyloxy)-2-azetidinone, (+)-9i. From 18 mg (0.059 mmol) of compound (+)-7i, 19 mg

(68%) of compound (+)-**9i** was obtained as a colorless oil. $[\alpha]_D = +97.9$ (*c* 1.9, CH₂Cl₂). ¹H-NMR: δ 2.03 (s, 3H), 2.31 (t, 2H, *J* = 6.7 Hz), 3.73 (s, 3H), 4.15 (ddt, 1H, *J* = 12.9, 5.8, 1.5 Hz), 4.28 (ddt, 1H, *J* = 12.9, 5.2, 1.5 Hz), 4.32 (t, 1H, *J* = 5.3 Hz), 4.69 (d, 1H, *J* = 5.3 Hz), 4.72 (m, 2H), 5.28 (m, 4H), 5.59 (s, 1H), 5.83 (m, 1H), 6.28 (dt, 2H, *J* = 8.8, 2.5 Hz), 7.28 (m, 7H). ¹³C-NMR: δ 169.7, 167.8, 164.9, 156.8, 133.8, 133.3, 132.0, 130.1, 129.1, 128.6, 127.8, 120.1, 118.6, 118.1, 114.3, 80.3, 74.1, 73.4, 72.3, 57.6, 55.5, 35.2, 20.7. IR (CHCl₃, cm⁻¹): ν 1750, 1648. MS (EI), *m/z* : 480 (*M*⁺ + 1, 40), 479 (*M*⁺, 100). (Anal. Calcd for C₂₇H₂₉NO₇: C, 67.63; H, 6.10; N, 2.92. Found: C, 67.53; H, 6.18; N, 2.82).

(R)-O-Acetylmandelate of (3R,4S)-4-[(S)-2,2-dimethyl-1,3-dioxolan-4-yl]-1-[(R)-2-hydroxy-4-pentenyl]-3-methoxy-2-azetidinone, (-)-12a. From 12 mg (0.042 mmol) of the compound (+)-**11b**, 18 mg (92%) of compound (-)-**12a** was obtained as a colorless oil. $[\alpha]_D = -22.5$ (*c* 1.8, CH₂Cl₂). ¹H-NMR: δ 1.21 and 1.35 (s, each 3H), 2.13 (s, 3H), 2.29 (dt, 2H, *J* = 6.5, 0.5 Hz), 2.83 (dd, 1H, *J* = 8.5, 5.1 Hz), 3.29 (m, 3H), 3.34 (s, 3H), 3.86 (m, 2H), 3.87 (d, 1H, *J* = 5.1 Hz), 5.00 (s, 1H), 5.08 (dt, 1H, *J* = 4.4, 1.2 Hz), 5.15 (m, 1H), 5.66 (m, 1H), 5.77 (s, 1H), 7.39 (m, 5H). ¹³C-NMR: δ 170.3, 168.2, 167.4, 133.8, 131.7, 129.3, 128.9, 127.9, 118.9, 109.4, 82.6, 74.6, 72.8, 66.5, 61.3, 59.1, 43.6, 36.5, 33.9, 26.8, 24.9, 20.7. IR (CHCl₃, cm⁻¹): ν 1750, 1650. MS (EI), *m/z* : 462 (*M*⁺ + 1, 15), 461 (*M*⁺, 60), 149 (100). (Anal. Calcd for C₂₄H₃₁NO₈: C, 62.46; H, 6.77; N, 3.03. Found: C, 62.32; H, 6.87; N, 2.95).

(S)-O-Acetylmandelate of (3R,4S)-4-[(S)-2,2-dimethyl-1,3-dioxolan-4-yl]-1-[(R)-2-hydroxy-4-pentenyl]-3-methoxy-2-azetidinone, (+)-12b. From 12 mg (0.042 mmol) of the compound (+)-**11b**, 17 mg (87%) of compound (+)-**12b** was obtained as a colorless oil. $[\alpha]_D = +39.5$ (*c* 1.7, CH₂Cl₂). ¹H-NMR: δ 1.28 and 1.42 (s, each 3H), 2.03 (dd, 2H, *J* = 14.1, 6.6 Hz), 2.13 (s, 3H), 3.37 (m, 2H), 3.45 (s, 3H), 3.57 (dd, 1H, *J* = 8.8, 5.8 Hz), 3.71 (dd, 1H, *J* = 8.8, 5.1 Hz), 4.04 (dd, 1H, *J* = 8.8, 6.6 Hz), 4.17 (m, 1H), 4.35 (d, 1H, *J* = 5.1 Hz), 4.67 (dq, 1H, *J* = 12.7, 1.7 Hz), 4.73 (dt, 1H, *J* = 4.4, 1.7 Hz), 5.29 (m, 2H), 5.76 (s, 1H), 7.36 (m, 5H). ¹³C-NMR: δ 170.3, 168.2, 167.7, 133.5, 131.4, 129.2, 128.6, 127.6, 118.5, 109.4, 82.9, 74.6, 72.9, 66.7, 61.4, 59.1, 43.8, 36.5, 33.9, 26.9, 24.9, 20.6. IR (CHCl₃, cm⁻¹): ν 1750, 1650. MS (EI), *m/z* : 462 (*M*⁺ + 1, 25), 461 (*M*⁺, 70), 149 (100). (Anal. Calcd for C₂₄H₃₁NO₈: C, 62.46; H, 6.77; N, 3.03. Found: C, 62.31; H, 6.77; N, 3.11).

Spectroscopic and analytical data for some representative forms of **17-19** follow.

Methanesulfonate of (3*R*,4*S*)-4-[(*RS*)-1-hydroxy-3-butenyl]-1-(*p*-methoxyphenyl)-3-methyl-2-azetidinone, **17a.** From 55 mg (0.210 mmol) of homoallylic alcohol **7a**, 74 mg (97%) of compound **17a** was obtained as a yellow solid after purification by flash chromatography (dichloromethane/ethyl acetate 9/1). Yellow solid. Mp: 104-106 °C (hexanes/ethyl acetate). ¹H-NMR: δ 1.37 (d, 3H, *J* = 7.7 Hz), 2.34 (s, 3H, *J* = 4.5 Hz), 2.48 and 2.66 (m, each 1H), 3.47 (dq, 1H, *J* = 7.8, 5.8 Hz), 3.75 (s, 3H), 4.38 (dd, 1H, *J* = 9.8, 5.8 Hz), 4.92 (m, 1H), 5.21 (m, 2H), 5.92 (m, 1H), 6.84 and 7.28 (d, each 2H, *J* = 9.0 Hz). ¹³C-NMR: δ 167.9, 156.7, 130.9, 130.7, 120.4, 114.3, 81.6, 55.6, 54.9, 46.0, 38.0, 37.6, 31.6, 9.9. IR (KBr, cm⁻¹): ν 1740, 1360, 1175. MS (EI), *m/z* : 340 (*M*⁺ + 1, 21), 339 (*M*⁺, 97), 149 (100). (Anal. Calcd for C₁₆H₂₁NSO₅: C, 56.62; H, 6.24; N, 4.13. Found: C, 56.64; H, 6.24; N, 4.16).

Methanesulfonate of (3*R*,4*S*)-4-[(*R*)-1-hydroxy-3-butenyl]-3-phenoxy-1-(2-propenyl)-2-azetidinone, (+)-17e**.** From 390 mg (1.43 mmol) of homoallylic alcohol (+)-**7e**, 395 mg (79%) of compound (+)-**17e** was obtained as a green pale oil after purification by flash chromatography (dichloromethane/ethyl acetate 9.5/0.5). Green pale oil. [α]_D = + 93.5 (*c* 0.9, CH₂Cl₂). ¹H-NMR: δ 2.61 (m, 2H), 3.00 (s, 3H), 3.73 (dd, 1H, *J* = 15.5, 7.5 Hz), 4.04 (dd, 1H, *J* = 7.0, 5.1 Hz), 4.25 (dd, 1H, *J* = 15.5, 5.0 Hz), 5.17 (m, 6H), 5.74 (m, 2H), 7.01 (m, 3H), 7.24 (m, 2H). ¹³C-NMR: δ 165.9, 157.2, 131.5, 130.9, 129.8, 122.8, 120.2, 119.8, 115.8, 80.2, 57.2, 44.1, 39.5, 37.3, 31.5. IR (CHCl₃, cm⁻¹): ν 1765, 1402, 1175. MS (EI), *m/z* : 352 (*M*⁺ + 1, 2), 351 (*M*⁺, 10), 131 (100). (Anal. Calcd for C₁₇H₂₁NSO₅: C, 58.1; H, 6.02; N, 3.99. Found: C, 58.16; H, 6.00; N, 4.00).

Methanesulfonate of (3*R*,4*S*)-4-[(*R*)-1-hydroxy-3-butenyl]-3-methoxy-1-(4-pentynyl)-2-azetidinone, (+)-17h**.** From 329 mg (1.39 mmol) of homoallylic alcohol (+)-**7h**, 468 mg (83%) of compound (+)-**17h** was obtained as a colorless oil after purification by flash chromatography (ethyl acetate/hexane 4/6). Colorless oil. [α]_D = + 43.0 (*c* 3.1, CH₂Cl₂). ¹H-NMR: δ 1.76 (m, 2H), 1.93 (t, 1H, *J* = 2.7 Hz), 2.15 (dd, 1H, *J* = 7.0, 2.7 Hz), 2.18 and 2.55 (m, each 1H), 3.00 (s, 3H), 3.18 (ddd, 1H, *J* = 14.0, 7.0, 6.0 Hz), 3.52 (s, 3H), 3.60 (dd, 1H, *J* = 14.0, 7.0 Hz), 3.86 (dd, 1H, *J* = 7.8, 5.1 Hz), 4.40 (d, 1H, *J* = 5.1 Hz), 4.94 (m, 1H), 5.12 (dq, 1H, *J* = 6.5, 1.5 Hz), 5.19 (s, 1H), 5.82 (m, 1H). ¹³C-NMR: δ 167.3, 131.6, 119.8, 82.8, 82.6, 81.0, 69.2, 59.1, 57.6, 40.6, 39.3, 36.9, 25.7, 16.1. IR (CHCl₃, cm⁻¹): ν 3310, 1750, 1360, 1176. MS (EI), *m/z* : 316 (*M*⁺ + 1, 7), 315 (*M*⁺, 51),

149 (100). (Anal. Calcd for $C_{14}H_{21}NSO_5$: C, 53.32; H, 6.71; N, 4.44. Found: C, 53.45; H, 6.60; N, 4.40).

Methanesulfonate of (3*R*,4*S*)-4-[(*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[(*S*)-2-hydroxy-4-pentenyl]-3-methoxy-2-azetidinone, (+)-18a. From 428 mg (1.50 mmol) of homoallylic alcohol (+)-11a, 545 mg (90%) of compound (+)-18a was obtained as a white solid after purification by flash chromatography (ethyl acetate/hexane 1/1). White solid. Mp: 87-88 °C (hexanes/ethyl acetate). $[\alpha]_D = +52.8$ (*c* 1.0, CH_2Cl_2). 1H -NMR: δ 1.34 and 1.41 (s, each 3H), 2.47 (dt, 2H, *J* = 1.1, 6.5 Hz), 3.03 (s, 3H), 3.40 (dd, 1H, *J* = 14.7, 3.3 Hz), 3.52 (s, 3H), 3.65 (dd, 1H, *J* = 8.5, 6.0 Hz), 3.74 (dd, 1H, *J* = 14.4, 8.5 Hz), 3.86 (dd, 1H, *J* = 9.2, 5.2 Hz), 4.12 (dt, 1H, *J* = 8.5, 1.5 Hz), 4.26 (dt, 1H, *J* = 8.8, 6.2 Hz), 4.47 (d, 1H, *J* = 5.2 Hz), 4.93 (m, 1H), 5.17 (s, 1H), 5.22 (d, 1H, *J* = 7.4 Hz), 5.79 (m, 1H). ^{13}C -NMR: δ 168.3, 131.5, 119.6, 109.6, 83.0, 76.4, 66.7, 60.0, 59.3, 44.0, 38.7, 37.2, 31.5, 26.8, 25.1. IR (KBr, cm^{-1}): ν 1746, 1356, 1177. MS (EI), *m/z* : 364 ($M^+ + 1$, 2), 363 (M^+ , 4), 72 (100). (Anal. Calcd for $C_{15}H_{25}NO_7S$: C, 49.57; H, 6.93; N, 3.85. Found: C, 49.54; H, 6.91; N, 3.84).

Methanesulfonate of (3*R*,4*S*)-4-[(*S*)-2,2-dimethyl-1,3-dioxolan-4-yl]-1-[(*R*)-2-hydroxy-4-pentenyl]-3-methoxy-2-azetidinone 18b. From 321 mg (1.13 mmol) of homoallylic alcohol (+)-11b, 368 mg (90%) of compound (+)-18b was obtained as a colorless oil after purification by flash chromatography (ethyl acetate/hexane 1/1). Colorless oil. $[\alpha]_D = +39.3$ (*c* 1.0, CH_2Cl_2). 1H -NMR: δ 1.36 and 1.44 (s, each 3H), 2.47 (tt, 2H, *J* = 7.0, 0.8, 7.0 Hz), 3.05 (s, 3H), 3.51 (m, 1H), 3.52 (s, 3H), 3.63 (dd, 1H, *J* = 8.5, 5.5 Hz), 3.76 (dd, 1H, *J* = 9.2, 5.2 Hz), 4.12 (dd, 1H, *J* = 8.5, 6.6 Hz), 4.34 (m, 1H), 4.48 (dd, 1H, *J* = 5.2, 0.8 Hz), 5.05 (m, 1H), 5.17 (s, 1H), 5.22 (dd, 1H, *J* = 5.9, 1.1 Hz), 5.80 (m, 1H). ^{13}C -NMR: δ 167.8, 131.5, 119.6, 109.6, 83.0, 78.9, 66.7, 61.8, 59.2, 44.7, 38.9, 37.6, 31.5, 26.9, 25.1. IR (KBr, cm^{-1}): ν 1745, 1357, 1175. MS (EI), *m/z* : 364 ($M^+ + 1$, 1), 363 (M^+ , 3), 72 (100). (Anal. Calcd for $C_{15}H_{25}NO_7S$: C, 49.57; H, 6.93; N, 3.85. Found: C, 49.53; H, 6.96; N, 3.89).

Methanesulfonate of (3*R*,4*S*)-4-[(*S*)-2,2-dimethyl-1,3-dioxolan-4-yl]-1-[(*RS*)-3-hydroxy-5-hexenyl]-3-methoxy-2-azetidinone, (+)-19. From 440 mg (1.47 mmol) of homoallylic alcohol (+)-13, 499 mg (90%) of compound (+)-19 was obtained as a colorless oil after purification by flash chromatography (ethyl acetate/hexane 1/1). Colorless oil. $[\alpha]_D = +49.8$ (*c* 2.5, CH_2Cl_2). 1H -NMR:

δ 1.27 and 1.37 (s, each 3H), 1.99 (m, 2H), 2.47 (m, 2H, $J = 6.5, 1.1$ Hz), 2.99 (s, 3H), 3.34 (m, 2H), 3.46 (s, 3H), 3.56 (dd, 1H, $J = 8.3, 5.6$ Hz), 3.62 (dd, 1H, $J = 8.8, 5.1$ Hz), 4.07 (m, 1H), 4.20 (m, 1H), 4.37 (d, 1H, $J = 5.1$ Hz), 4.69 (m, 1H), 5.08 (d, 1H, $J = 0.7$ Hz), 5.17 (dd, 1H, $J = 4.4, 1.2$ Hz), 5.71 (m, 1H). ^{13}C -NMR: δ 167.8 (M), 167.7 (m), 131.9 (m), 131.8 (M), 119.4 (M + m), 109.5 (M + m), 82.6 (M), 82.5 (m), 79.9 (M), 79.6 (m), 76.8 (M), 76.7 (m), 66.6 (M + m), 60.7 (M), 60.4 (m), 59.1 (M + m), 38.9 (M + m), 38.6 (M + m), 37.9 (M), 37.0 (m), 31.8 (M), 31.3 (m), 26.7 (M + m), 25.0 (M + m). IR (CHCl_3 , cm^{-1}): ν 1748, 1355, 1173. MS (EI), m/z : 378 ($\text{M}^+ + 1, 2$), 363 (M^+ , 6), 72 (100). (Anal. Calcd for $\text{C}_{16}\text{H}_{27}\text{NO}_7\text{S}$: C, 50.91; H, 7.21; N, 3.71. Found: C, 50.78; H, 7.17; N, 3.75).

Spectroscopic and analytical data for some representative forms of **20-22** follow.

(3SR,4SR)-4-[(1E)-1,3-Butadienyl]-1-(*p*-methoxyphenyl)-3-methyl-2-azetidinone, 20a.

From 96 mg (0.282 mmol) of methanesulfonate **17a**, 51 mg (75%) of compound **20a** was obtained as a colorless oil after purification by flash chromatography (dichloromethane/ethyl acetate 9.5/0.5). Colorless oil. ^1H -NMR: δ 1.15 (d, 3H, $J = 7.6$ Hz), 3.45 (qd, 1H, $J = 7.5, 5.9$ Hz), 3.70 (s, 3H), 4.51 (dd, 1H, $J = 8.0, 5.9$ Hz), 5.12 (dd, 1H, $J = 8.5, 1.5$ Hz), 5.20 (dd, 1H, $J = 16.1, 1.8$ Hz), 5.65 (m, 1H), 5.89 (m, 2H), 6.77 and 7.28 (dd, each 2H, $J = 6.6, 2.5$ Hz). ^{13}C -NMR: δ 167.7, 155.9, 136.0, 135.6, 131.7, 128.5, 118.8, 118.1, 114.2, 56.8, 55.4, 49.8, 9.8. IR (CHCl_3 , cm^{-1}): ν 1734. MS (EI), m/z : 244 ($\text{M}^+ + 1, 5$), 243 (M^+ , 25), 149 (100). (Anal. Calcd for $\text{C}_{15}\text{H}_{17}\text{NO}_2$: C, 74.05; H, 7.04; N, 5.76. Found: C, 74.06; H, 7.00; N, 5.75).

(3R,4S)-4-[(1E)-1,3-Butadienyl]-3-phenoxy-1-(2-propenyl)-2-azetidinone, (+)-20e. From 120 mg (0.342 mmol) of methanesulfonate **(+)-17e**, 58 mg (66%) of compound **(+)-20e** was obtained as a yellow solid after purification by flash chromatography (dichloromethane/ethyl acetate 9.5/0.5). Yellow solid. Mp: 85-86 °C (Hexanes/ethyl acetate). $[\alpha]_{\text{D}} = +5.5$ (c 1.0, CH_2Cl_2). ^1H -NMR: δ 3.52 (dd, 1H, $J = 15.5, 7.0$ Hz), 4.03 (dd, 1H, $J = 15.5, 5.1$ Hz), 4.34 (dd, 1H, $J = 8.8, 4.4$ Hz), 5.17 (m, 4H), 5.23 (d, 1H, $J = 4.5$ Hz), 5.67 (m, 2H), 6.24 (m, 2H), 6.89 (m, 3H), 7.20 (m, 2H). ^{13}C -NMR: δ 165.2, 157.3, 137.8, 135.7, 131.1, 129.5, 126.1, 122.2, 119.2, 119.0, 115.5, 81.9, 60.2, 42.8. IR (KBr, cm^{-1}): ν 1751. MS (EI), m/z : 256 ($\text{M}^+ + 1, 3$), 255 (M^+ , 9), 59 (100). (Anal. Calcd for $\text{C}_{16}\text{H}_{17}\text{NO}_2$: C, 75.27; H, 6.71; N, 5.49. Found: C, 75.24; H, 6.75; N, 5.50).

(3R,4S)-4-[(1E)-1,3-Butadienyl]-3-methoxy-1-(4-pentynyl)-2-azetidinone, (+)-20h. From 100 mg (0.318 mmol) of methanesulfonate (+)-17h, 64 mg (92%) of compound (+)-20h was obtained as a colorless oil after purification by flash chromatography (ethyl acetate/hexane 4/6). Colorless oil. $[\alpha]_D = +36.7$ (c 3.0, CH₂Cl₂). ¹H-NMR: δ 1.69 (m, 2H), 1.91 (t, 1H, $J = 2.7$ Hz), 2.16 (dt, 2H, $J = 7.0, 2.7$ Hz), 3.07 (td, 1H, $J = 14.0, 7.0$ Hz), 3.27 (dd, 1H, $J = 14.0, 7.0$ Hz), 3.37 (s, 3H), 4.12 (dd, 1H, $J = 9.0, 4.4$ Hz), 4.48 (d, 1H, $J = 4.4$ Hz), 5.20 (m, 2H), 5.65 (m, 1H), 6.31 (dd, 1H, $J = 14.5, 10.0$ Hz), 6.35 (td, 1H, $J = 16.5, 10.0$ Hz). ¹³C-NMR: δ 166.9, 137.4, 135.9, 127.3, 119.2, 85.4, 82.9, 69.3, 60.7, 58.7, 39.5, 26.7, 16.3. IR (CHCl₃, cm⁻¹): ν 3310, 1748. MS (EI), m/z : 220 ($M^+ + 1$, 7), 219 (M^+ , 14), 91 (100). (Anal. Calcd for C₁₃H₁₇NO₂: C, 71.21; H, 7.81; N, 6.39. Found: C, 71.11; H, 7.63; N, 6.51).

Preparation of Dienes 21-23.

From 100 mg (3.31 mmol) of the methanesulfonate (+)-18, and after flash chromatography eluting with ethyl acetate/hexane (4:6), 7 mg (10%) of the less polar compound (+)-23 and 52 mg (70%) of the more polar compound (-)-21 were obtained.

(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-(2,4-pentadienyl)-3-methoxy-2-azetidinone, (-)-21. Colorless oil. $[\alpha]_D = -3.8$ (c 0.5, CH₂Cl₂). ¹H-NMR: δ 1.35 and 1.43 (s, each 3H), 3.54 (s, 3H), 3.63 (dd, 1H, $J = 8.8, 5.5$ Hz), 3.66 (dd, 1H, $J = 8.8, 5.1$ Hz), 3.77 (dd, 1H, $J = 15.0, 8.0$ Hz), 4.12 (ddd, 1H, $J = 8.8, 6.6, 0.7$ Hz), 4.19 (dd, 1H, $J = 15.0, 9.5$ Hz), 4.28 (dt, 1H, $J = 8.8, 6.2$ Hz), 4.42 (d, 1H, $J = 5.1$ Hz), 5.16 (m, 2H), 5.63 (m, 1H), 6.19 (dd, 1H, $J = 14.7, 10.5$ Hz), 6.32 (td, 1H, $J = 16.5, 10.5$ Hz). ¹³C-NMR: δ 167.1, 136.0, 135.0, 126.5, 117.9, 109.5, 82.8, 76.9, 66.7, 59.7, 59.1, 42.6, 26.7, 25.1. IR (CHCl₃, cm⁻¹): ν 1750. MS (EI), m/z : 268 ($M^+ + 1$, 1), 267 (M^+ , 3), 72 (100). (Anal. Calcd for C₁₄H₂₁NO₄: C, 62.9; H, 7.92; N, 5.24. Found: C, 62.84; H, 7.90; N, 5.25).

(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[1,4-pentadienyl]-3-methoxy-2-azetidinone, (+)-23. Colorless oil. $[\alpha]_D = +119.3$ (c 1.0, CH₂Cl₂). ¹H-NMR: δ 1.29 and 1.40 (s, each 3H), 2.72 (t, 2H, $J = 6.5$ Hz), 3.49 (s, 3H), 3.60 (dd, 1H, $J = 8.8, 6.3$ Hz), 3.81 (dd, 1H, $J = 8.8, 5.5$ Hz), 4.11 (dd, 1H, $J = 8.8, 7.0$ Hz), 4.23 (dt, 1H, $J = 8.8, 6.3$ Hz), 4.39 (d, 1H, $J = 5.5$ Hz), 4.96 (d, 1H, $J = 9.9$ Hz), 5.00 (d, 1H, $J = 18.0$ Hz), 5.77 (m, 2H), 6.32 (d, 1H, $J = 15.1$ Hz). IR (CHCl₃,

cm^{-1}): ν 1747. MS (EI), m/z : 268 ($M^+ + 1$, 1), 267 (M^+ , 3), 72 (100). (Anal. Calcd for $\text{C}_{14}\text{H}_{21}\text{NO}_4$: C, 62.9; H, 7.92; N, 5.24. Found: C, 61.88; H, 7.89; N, 5.29).

(3R,4S)-4-[(S)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[3,5-hexadienyl]-3-methoxy-2-azetidinone, (+)-22. From 280 mg (0.743 mmol) of methanesulfonate (+)-19, 120 mg (58%) of compound (+)-22 was obtained as a colorless oil after purification by flash chromatography (ethyl acetate/hexane 4/6). Colorless oil. $[\alpha]_D = +61.4$ (c 2.5, CH_2Cl_2). $^1\text{H-NMR}$: δ 1.28 and 1.35 (s, each 3H), 2.34 (q, 2H, $J = 7.0$ Hz), 3.21 (m, 2H), 3.45 (s, 3H), 3.54 (m, 2H), 4.06 (dd, 1H, $J = 8.5$, 6.5 Hz), 4.18 (td, 1H, $J = 8.8$, 6.5 Hz), 4.32 (d, 1H, $J = 4.9$ Hz), 4.97 (dd, 1H, $J = 19.5$, 1.0 Hz), 5.04 (dd, 1H, $J = 26.5$, 1.5 Hz), 5.56 (m, 1H), 6.03 (dd, 1H, $J = 14.9$, 10.2 Hz), 6.24 (td, 1H, $J = 16.5$, 10.5 Hz). $^{13}\text{C-NMR}$: δ 167.7, 136.9, 133.2, 131.0, 116.1, 109.6, 82.8, 66.9, 60.6, 59.2, 40.7, 30.9, 27.0, 25.2. IR (CHCl_3 , cm^{-1}): ν 1739. MS (EI), m/z : 282 ($M^+ + 1$, 2), 281 (M^+ , 4), 91 (100). (Anal. Calcd for $\text{C}_{15}\text{H}_{23}\text{NO}_4$: C, 64.04; H, 8.24; N, 4.98. Found: C, 64.11; H, 8.20; N, 4.99).

General Procedure for the Preparation of Compounds 25-28.

Carboxymethyltriphenylphosphorane (201 mg, 0.60 mmol) was added in portions to a stirred solution of the corresponding 4-oxoazetidine-2-carbaldehyde (0.5 mmol) in dichloromethane (4 mL) at 0 °C and the mixture was stirred for 16 h at room temperature, before being concentrated under reduced pressure. Chromatography of the residue eluting with hexanes/ethyl acetate mixtures gave analytically pure compounds 25-28.

From 148 mg (0.760 mmol) of the aldehyde (+)-11, and after flash chromatography eluting with ethyl acetate/hexane (1:1), 41 mg (22%) of the less polar compound (+)-26 and 119 mg (63%) of the more polar compound (+)-25 were obtained.

(+)-(3R,4S,4E)-4-(Carboxymethylen)-3-methoxy-1-(2,4-pentadienyl)-2-azetidinone, (+)-25. Colorless oil. $[\alpha]_D = +23.0$ (c 7.0, CH_2Cl_2). $^1\text{H-NMR}$: δ 3.38 (s, 3H), 3.52 (dd, 1H, $J = 15.5$, 8.0 Hz), 3.70 (s, 3H), 4.04 (ddd, 1H, $J = 15.5$, 5.4, 0.5 Hz), 4.23 (ddd, 1H, $J = 8.5$, 4.6, 0.7 Hz), 4.58 (d, 1H, $J = 4.6$, Hz), 5.08 (d, 1H, $J = 13.9$ Hz), 5.14 (dd, 1H, $J = 20.7$, 1.7 Hz), 5.47 (m, 1H), 6.02 (dd, 1H, $J = 15.9$, 0.7 Hz), 6.06 (dd, 1H, $J = 15.0$, 10.2 Hz), 6.30 (td, 1H, $J = 16.5$, 10.2 Hz), 6.82 (dd, 1H, $J = 15.9$, 8.5 Hz). $^{13}\text{C-NMR}$: δ 165.9, 165.5, 141.6, 135.5, 135.3, 126.3, 125.6, 118.6, 85.8, 58.8, 58.3, 51.8, 42.1. IR (CHCl_3 , cm^{-1}): ν 1759, 1724. MS (EI), m/z : 252 ($M^+ + 1$, 7), 251

(M⁺, 19), 91 (100). (Anal. Calcd for C₁₃H₂₇NO₄: C, 62.14; H, 6.82; N, 5.57. Found: C, 62.08; H, 6.92; N, 5.45).

(+)-(3R,4S,4Z)-4-(Carboxymethylen)-3-methoxy-1-(2,4-pentadienyl)-2-azetidinone, (+)-26. Colorless oil. [α]_D = + 63.0 (c 4.3, CH₂Cl₂). ¹H-NMR: δ 3.37 (s, 3H), 3.66 (s, 3H), 3.67 and 3.83 (ddd, each 1H, *J* = 15.5, 6.5, 0.5 Hz), 4.61 (d, 1H, *J* = 4.7 Hz), 5.06 and 5.12 (s, each 1H), 5.29 (ddd, 1H, *J* = 8.5, 4.7, 1.0 Hz), 5.51 (td, 1H, *J* = 14.6, 6.8 Hz), 6.02 (dd, 1H, *J* = 11.5, 1.0 Hz), 6.20 (m, 3H). ¹³C-NMR: δ 166.7, 166.1, 143.6, 135.9, 135.1, 126.4, 124.7, 118.5, 85.9, 59.1, 55.7, 51.7, 42.7. IR (CHCl₃, cm⁻¹): ν 1759, 1720. MS (EI), *m/z* : 252 (M⁺ + 1, 5), 251 (M⁺, 13), 91 (100). (Anal. Calcd for C₁₃H₂₇NO₄: C, 62.14; H, 6.82; N, 5.57. Found: C, 62.18; H, 6.70; N, 5.51).

From 85 mg (0.407 mmol) of the aldehyde (+)-24, and after flash chromatography eluting with ethyl acetate/hexane (1:1), 38 mg (35%) of the less polar compound (+)-28 and 53 mg (50%) of the more polar compound (+)-27 were obtained.

(+)-(3R,4S,4E)-4-(Carboxymethylen)-1-(3,5-hexadienyl)-3-methoxy-2-azetidinone, (+)-27. Colorless oil. [α]_D = + 113.7 (c 3.0, CH₂Cl₂). ¹H-NMR : δ 2.25 (m, 2H), 3.05 (dd, 1H, *J* = 14.0, 7.0 Hz), 3.36 (s, 3H), 3.38 (dd, 1H, *J* = 14.0, 7.0 Hz), 3.71 (s, 3H), 4.21 (ddd, 1H, *J* = 8.5, 4.6, 0.7 Hz), 4.55 (d, 1H, *J* = 4.6 Hz), 4.99 (dt, 1H, *J* = 17.3, 0.7 Hz), 5.05 (dd, 1H, *J* = 24.6, 1.7 Hz), 5.50 (m, 1H), 6.03 (dd, 1H, *J* = 15.0, 10.2 Hz), 6.04 (dd, 1H, *J* = 15.9, 0.7 Hz), 6.23 (td, 1H, *J* = 16.5, 10.2 Hz), 6.83 (dd, 1H, *J* = 15.9, 8.5 Hz). ¹³C-NMR: δ 166.3, 165.5, 141.7, 136.4, 133.6, 129.9, 126.2, 116.5, 85.6, 59.0, 58.8, 51.8, 40.0, 30.9. IR (CHCl₃, cm⁻¹): ν 1757, 1720. MS (EI), *m/z* : 266 (M⁺ + 1, 2), 265 (M⁺, 5), 111 (100). (Anal. Calcd for C₁₄H₁₉NO₄: C, 63.38; H, 7.22; N, 5.28. Found: C, 63.42; H, 7.24; N, 5.22).

(+)-(3R,4S,4Z)-4-(Carboxymethylen)-1-(3,5-hexadienyl)-3-methoxy-2-azetidinone, (+)-28. Colorless oil. [α]_D = + 74.0 (c 1.0, CH₂Cl₂). ¹H-NMR: δ 2.27 (q, 2H, *J* = 7.3 Hz), 3.04 and 3.34 (dd, each 1H, *J* = 14.0, 7.0 Hz), 3.35 (s, 3H), 3.70 (s, 3H), 4.57 (d, 1H, *J* = 4.6 Hz), 4.95 (dt, 1H, *J* = 18.8, 0.7 Hz), 5.04 (dd, 1H, *J* = 24.4, 2.0 Hz), 5.31 (dd, 1H, *J* = 8.5, 4.6 Hz), 5.52 (m, 1H), 6.03 (dd, 1H, *J* = 16.5, 10.2 Hz), 6.04 (dd, 1H, *J* = 11.0, 0.7 Hz), 6.20 (m, 2H). ¹³C-NMR: δ 167.0, 166.0, 143.7, 136.7, 133.5, 130.3, 124.8, 116.3, 85.6, 58.9, 55.6, 51.7, 40.3, 31.0. IR (CHCl₃, cm⁻¹): ν 1757, 1720. MS (EI), *m/z* : 266 (M⁺ + 1, 3), 265 (M⁺, 7), 111 (100). (Anal. Calcd for C₁₄H₁₉NO₄: C, 63.38; H, 7.22; N, 5.28. Found: C, 63.42; H, 7.34; N, 5.22).

Preparation of Azetidine (+)-32. Diethyl ether (3.5 mL) was slowly added to lithium aluminum hydride (31 mg, 0.81 mmol) and aluminum(III) chloride (108 mg, 0.81 mmol), and the mixture was heated under reflux temperature for 30 min. The resulting suspension was allowed to cool to room temp. and the β -lactam (+)-20f (70 mg, 0.27 mmol) was added dropwise. After 15 min. at room temp., the mixture was cooled to 0 °C and water (1 mL) was added. The reaction was allowed to warm to room temp., before being partitioned between ether and water. The organic extract was washed with brine, dried (MgSO₄) and concentrated under reduced pressure to give 53 mg (81%) as a colorless oil.

(3*R*,4*S*,4*E*)-4-[1,3-Butadienyl]-3-phenoxy-1-(2-propenyl)azetidine (+)-32. Colorless oil. $[\alpha]_D^{25} = +77.8$ (*c* 1.0, CH₂Cl₂). ¹H-NMR: δ 2.96 and 3.20 (dd, each 1H, *J* = 13.4, 6.8 Hz), 3.23 (dd, 1H, *J* = 5.8, 1.5 Hz), 3.43 (dq, 1H, *J* = 9.0, 1.2 Hz), 3.89 (dt, 1H, *J* = 6.8, 0.5 Hz), 4.79 (dt, 1H, *J* = 5.8, 2.2 Hz), 5.08 (m, 4H), 5.75 (ddd, 1H, *J* = 16.0, 10.0, 1.0 Hz), 5.92 (ddd, 1H, *J* = 14.0, 6.3, 0.7 Hz), 6.22 (m, 2H), 6.71 (dt, 2H, *J* = 7.8, 1.0 Hz), 6.86 (tt, 1H, *J* = 7.5, 1.0 Hz), 7.17 (m, 2H). IR (CHCl₃, cm⁻¹): ν 3100. MS (EI), *m/z* : 242 (*M*⁺ + 1, 25), 241 (*M*⁺, 100). (Anal. Calcd for C₁₆H₁₉NO: C, 79.63; H, 5.80; N, 5.80. Found: C, 79.51; H, 8.04; N, 5.72).