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Towards EPC-syntheses of the structural class of cochleamycins and macquarimicins. Part 1: EPC-synthesis of the hydrindene subunit of the cochleamycins

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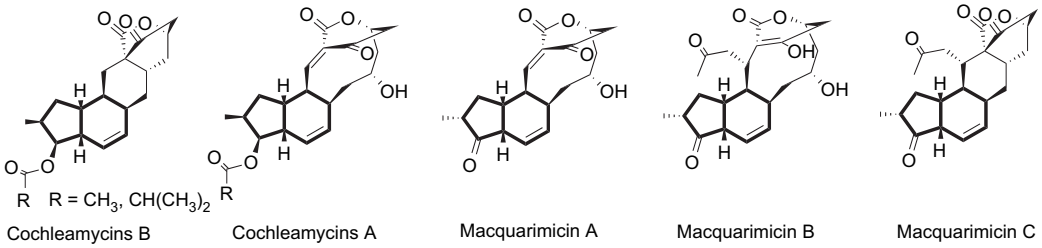
Abstract—A racemic as well as an EPC-synthesis of the *cis*-hydrindene subunit of the cochleamycins, physiologically active microbial secondary metabolites, are reported. The five stereogenic centres of this subunit are introduced in high stereoselectivity in a short sequence by intermolecular Diels–Alder reaction, stereoselective methylation and hydride reduction. Cyclisation via nucleophilic addition, acidic fragmentation, regioselective Shapiro reaction and inversion of a secondary alcohol are the further key steps of these syntheses.

1. Introduction

The increasing resistance of bacterial pathogens, viruses, and tumour cells necessitates the development of new and effective drugs.[1] Total synthesis can play an important role in defining the chemistry of such drugs, often leading to their improved efficacy. Since cross-resistance is less likely in antibiotics with structural features deviating strongly from the usually administered ones we chose as synthetic targets a small group of acetogenic macrolides, the cochleamycins[2,3] and the macquarimicins[6] (Scheme 1). Their structures include within a tetra- and pentacyclic ring system, respectively, a *cis*-hydrindene moiety and a bridged β-keto-δ-lactone. So far only very few bridged β-ketolactones have been detected in microbial secondary metabolites.[8]

Shindo et al. isolated cochleamycins A and B within a screening programmme for antitumour drugs from *Streptomyces* sp. in 1992.[2] Later on they confirmed the suggested structure of these tetra- and pentacyclic compounds with eight and nine stereogenic centres, respectively, by extensive NMR spectroscopy.[3] In additional papers they reported the antitumour activity of the penta- and tetracyclic compounds and the antibacterial activity of the cochleamycins A.[4] They also examined the biosynthesis of these compounds, establishing their acetogenic pathway.[5] Independently McAlpine et al. isolated the structurally closely related macquarimicins from a different family of Actinomycetales.[6] This *Micromonospora* sp. yielded macquarimicins A, B and C, which showed significant activity against Gram negative bacteria especially against *Bacteroides* sp., a group more resistant than most anaerobes against available antimicrobial agents. Like the cochleamycins they showed activity against leukaemia cell lines.[6] More recently, the anti-inflammatory activity of macquarimicin A was reported.[7] Their broad physiological activities and their intriguing structures stimulated considerable interest in synthesizing these compounds. Shortly after Sorensen et al.[9] and Evans and Starr[10] had mastered the construction of the bridged β-ketolactone in their syntheses of the structurally related FR 182877, Tatsuta et al. published



Scheme 1.

Keywords: Cochleamycin; Total synthesis; Substituted *cis*-hydrindenes; Annulation.
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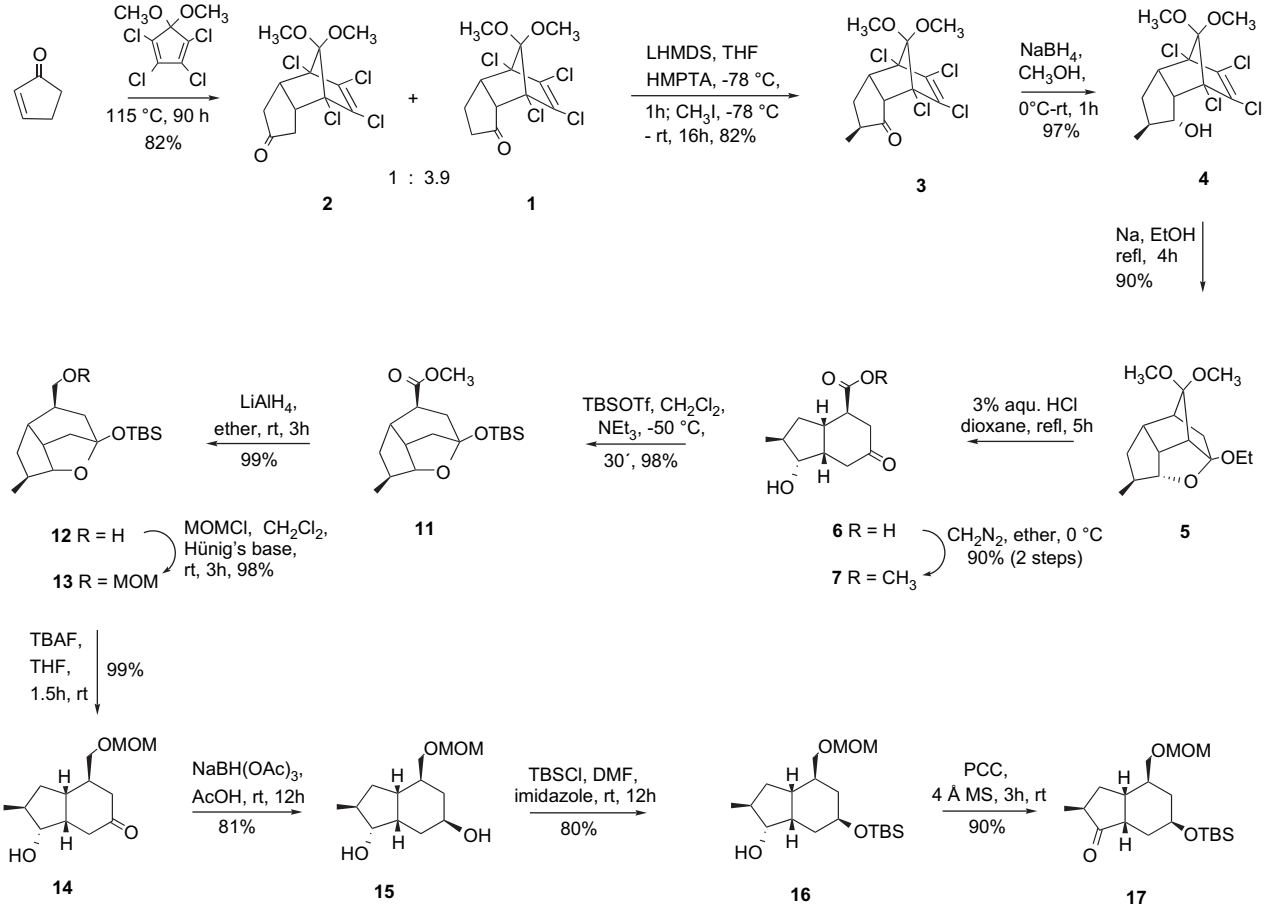
the first synthesis of cochleamycin A.[11] Their synthesis confirmed its structure and established its absolute configuration. In the same year Tadano et al. completed the synthesis of macquarimicin A, thereby revising the geometry of the double bond in the macrocyclic part of this antibiotic.[12] They then demonstrated the easy conversion of macquarimicin A not only to macquarimicin B but also to the pentacyclic macquarimicin C.[13] These syntheses as well as the synthesis of cochleamycin A by Roush and Dineen[14] and the synthetic efforts published so far[15] were based on the proposed key step in the biosynthesis of these acetogenic macrolides, the intramolecular and transannular Diels–Alder reaction.[5]

Our own synthetic plan deviates from these biomimetic concepts.[16] To achieve efficient and flexible syntheses we looked for high convergence by independently synthesizing two subunits, the 6-substituted-β-keto-δ-lactones and the *cis*-hydrindene moiety, combining them at a very late stage in the syntheses. This in turn should permit the syntheses of each of the known antibiotics by small variations in the synthesis of the subunits.

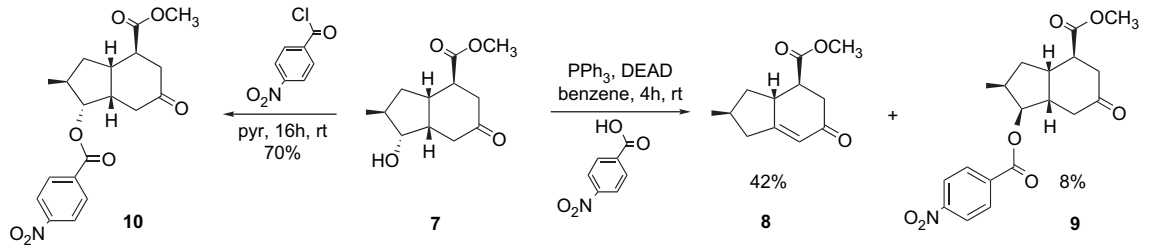
2. Racemic synthesis of the hydrindene subunit of the cochleamycins

To gain high stereoselectivity we used an annulation method developed in our laboratories (Scheme 2).[17]

Cycloaddition of commercially available 1,2,3,4-tetrachloro-5,5-dimethoxycyclopentadiene and cyclopent-2-enone at 115 °C for 90 h afforded the tricyclic ketone **1**[17b] containing small amounts of the symmetrical cycloadduct **2**. Obviously, even at temperatures as low as 115 °C isomerization of cyclopent-2-enone to the deconjugated cyclopent-3-enone is not totally suppressed. After examining various methods,[18] best results in the following methylation were accomplished with methyl iodide, lithium hexamethyldisilazane, and HMPTA in THF at −78 °C, which led stereoselectively to the desired *exo* methyl ketone **3** in good yield and only small amounts of byproducts (dimethylation and O-methylation).[16a] As expected, sodium borohydride reduced ketone **3** exclusively from the less hindered convex face to *endo* alcohol **4** despite the steric hindrance by the newly introduced *exo* methyl group. Treatment of *endo* alcohol **4** with sodium in refluxing ethanol yielded the tetracyclic diketal **5**, which by acidic fragmentation rendered the hydrindanone carboxylic acid **6**. Within this short and high yielding reaction sequence (five steps, 53% yield) the stereogenic centres of the targeted hydrindene subunit were introduced with high stereoselectivity and with the correct relative configuration with exception of the carbon centre at the secondary alcohol. We were confident that inversion of the secondary alcohol could be easily achieved. Thus after esterification of **6** with diazomethane, we intended to prepare the *exo* alcohol via Mitsunobu reaction (Scheme 3).[19]



Scheme 2.



Scheme 3.

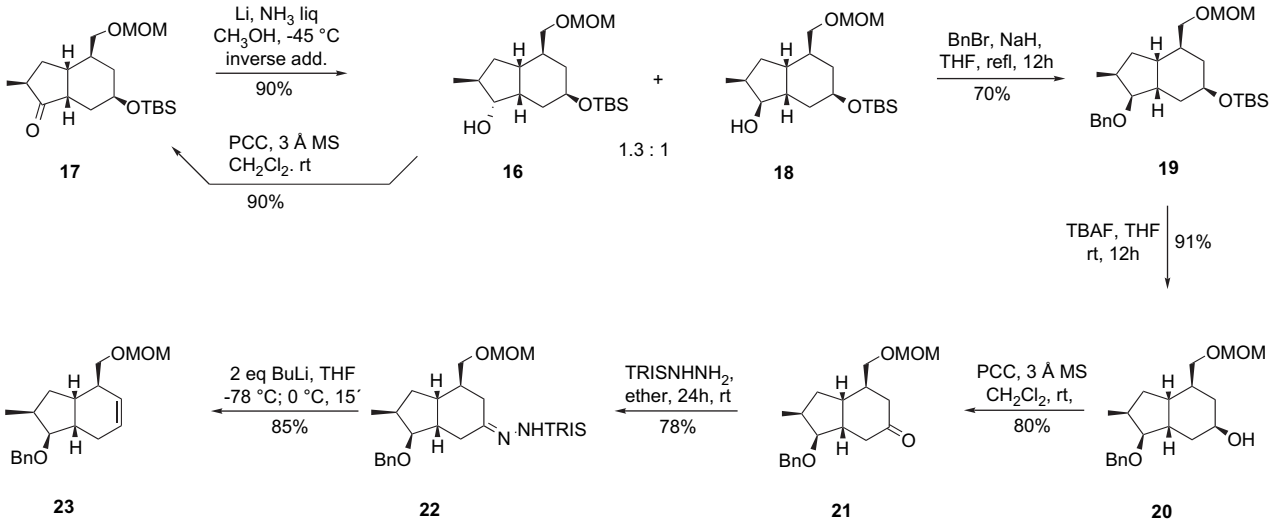
With all but one of many variants of the Mitsunobu reaction examined with ester **7**, the only product isolated was the conjugated enone **8**, derived by dehydration and subsequent enolization. Even in the single exception following Martin's Dodge's procedure[19b] the enone was the main product and only 8% of the inverted *p*-nitrobenzoate **9** was detected. To prove that at least the inversion had occurred in the Mitsunobu reaction, alcohol **7** was conventionally esterified. Indeed, the two *p*-nitrobenzoates **9** and **10** were not identical. Attempts to invert the alcohol via sulfonates and substitution with soft nucleophiles failed too.[20c–e] In structurally crowded ring fused cyclopentanols oxidation and subsequent reduction were found to be the method of choice.[21] Thus the keto as well as the hydroxy group of **7** was protected as cyclic *tert*-butyldimethylsilyl ketal **11** using highly reactive *tert*-butyldimethylsilyl triflate as silylation reagent.[22] Subsequently, the ester group of **11** was reduced by lithium aluminum hydride. Protection of the primary alcohol **12** as methoxymethyl ether **13** was followed by fluoride assisted cleavage of the cyclic ketal. This permitted directed reduction of ketone **14** with triacetoxy borohydride according to Evans et al.[23] Due to large differences in steric hindrance, the *exo* alcohol of **15** was regioselectively protected as *tert*-butyldimethylsilyl ether **16** with *tert*-butyldimethylsilyl chloride as silylation reagent.[24] Subsequently the *endo* alcohol was oxidized to ketone **17**. After checking various hydrides,[25] which rendered the *endo* alcohol **16** and smaller amounts of the desired *exo* alcohol **18** in the range of 3:1 to 4:1, we turned to dissolved metal reduction (Scheme 4).[26]

Assuming that the free electron in the ketyl radical and the free electron pair in the subsequent carbanion as the least voluminous 'groups' would occupy the most hindered position, alcohols with the opposite configuration as found with hydride reduction could be expected. Again we were disappointed. The *endo* alcohol **16** was the main product, but the ratio between *exo* to *endo* alcohol was more favourable. Table 1 shows our efforts to steer the dissolved metal reduction towards the *exo* alcohol.

Table 1. Birch reduction of ketone **17**

Entry	Amine	Addend	Metal	Temperature [°C]	Yield [%]	*endo*/*exo*
1	NH_3	MeOH	Li	−50	97	2/1
2	NH_3	*t*-BuOH	K	−78	90	7.7/1
3	NH_3	*t*-BuOH	Na	−78	82	4.5/1
4	NH_3	Ether	K	−33	79	2.8/1
5	NH_3	Ether	Li	−33	95	2.3/1
6	NH_3	Ether	Na	−33	78	2.6/1
7	NH_3	MeOH	Li	−78	76	2/1
8	NH_3	MeOH	Li	−33	87	1.6/1
9	NH_3	MeOH	Li/LiBr	−45	80	1.8/1
10	NH_3	EtOH	Li	−33	87	1.8/1
11	$PrNH_2$	MeOH	Li	0	66[a]	—
12	$PrNH_2$	MeOH	Li	50	66[a]	—
13	NH_3	EtOH/Ether	Na	−33	93	2.1/1
14	NH_3	MeOH/Ether	Na	−33	75	1.7/1
15	NH_3	MeOH/Ether	Ca	−40	64	3/1
16	NH_3	MeOH/Ether	Li[b]	−33	68	1.7/1
17	NH_3	MeOH/Ether	Li[b]	−45	97	1.3/1

[a] Starting material.
[b] Inverse addition.



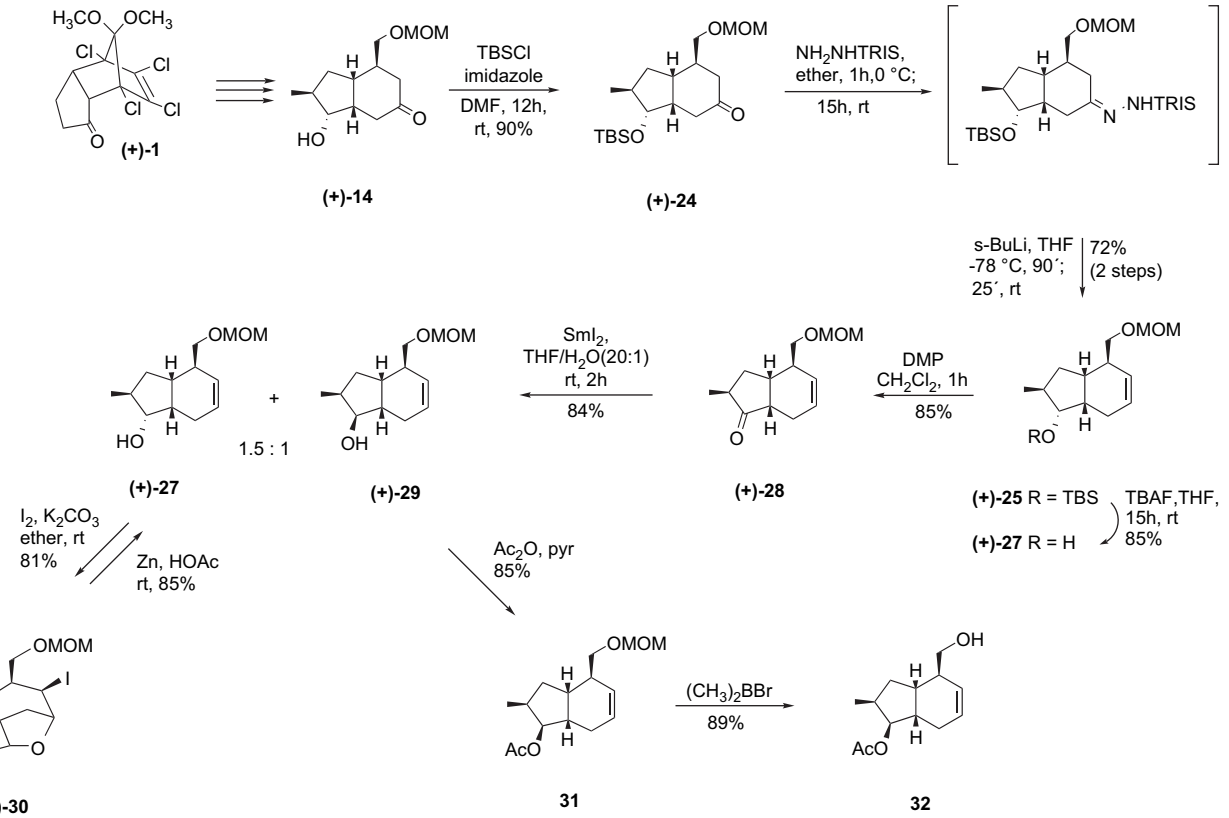
Scheme 4.

The smallest ratio of the two alcohols (**16/18**=1.3:1) was accomplished with inverse addition of lithium in ammonia to ketone **17** in dry methanol at −45 °C. Easy separation of the alcohols allowed recycling of *endo* alcohol **16** via reoxidation and reduction. With two cycles, the desired *exo* alcohol **18** was obtained in acceptable 75% yield. To introduce the double bond via ketone **21**, the hydroxy group was protected as benzyl ether **19** and the silyl ether was cleaved. The obtained alcohol **20** was oxidized to ketone **21**. Best yields and highest regioselectivity were achieved using Shapiro's procedure.[16c,27] Although the trisylhydrazones **22** (*E*/*Z*~9:1) could be purified on silica gel, higher yields were gained when freshly prepared trisylhydrazide was used to obtain the intermediate unstable trisylhydrazones **22**, which were immediately converted to the corresponding hydrindene derivative **23**, with *sec*-butyllithium as the most suitable base. We assume that steric hindrance is the main reason for the preferred formation of the (*E*)-trisylhydrazone isomer. Consequent addition of 2 equiv of the strong lithium base leads to abstraction of the hydrogen at C(3) due to the directing effect of nitrogen.[27b] The position of the double bond of the main product **23** was ascertained by NOESY experiments.

3. EPC-synthesis of the hydrindene subunit of the cochleamycins

With enantiomerically pure ketone (+)-**1** prepared as described in the succeeding paper,[28] we followed the path of our racemic synthesis up to bicyclic ketone **14**. Here we deviated from the racemic pathway by rearranging the sequence of the remaining steps (Scheme 5).

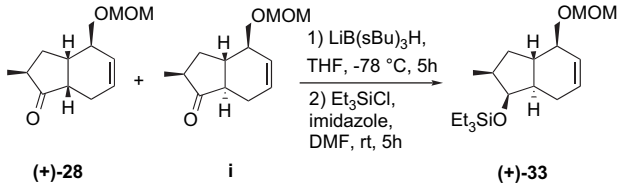
The alcohol group of **14** was protected as silyl ether **24** using (compared to reaction **7** to **11**) less acidic *tert*-butyldimethylsilyl chloride and imidazole as base.[24] Silyl ether **24** was transformed to the hydrindenes **25** and **26** by Shapiro reaction in good regioselectivity (Δ^3/Δ^4=10.5:1). In this way protection steps are spared and we hoped that with the hydrindene system elimination would no longer dominate the Mitsunobu reaction or that at least better access for hydride attack to the less crowded α-face of the more flattened shape of the bicyclic enone **28** could be gained. Thus alcohol **27** obtained by deprotection of silyl ether **25** was subjected to many variants of the Mitsunobu reaction.[19] In most cases small amounts (<10%) of the desired *exo* ester could be isolated but elimination dominated by far. Even with Wovkulich's protocol, expressly developed to repress elimination[19h] in the Mitsunobu reaction, or with picolinic acid,[19g] or by addition of an excess of sodium acetate or cesium acetate to the reaction mixture of conventional Mitsunobu conditions, no decisive improvement could be achieved. Other recently developed inversion methods were to no avail.[20] Again we had to depend on oxidation and reduction. The secondary alcohol **27** was oxidized to the ketone **28** by Dess–Martin periodinane.[29] Despite the expected smaller steric hindrance, sodium borohydride and other hydrides examined led to less favourable ratios of *endo* to *exo* alcohol as in the racemic synthesis. Dissolved metal reduction too led to slightly less favourable ratios of *endo* to *exo* alcohol as discovered with compound **17**. Additionally, a new complication surfaced. Whereas racemic ketone **17** was cleanly reduced to the mixture of *endo* and *exo* alcohols, the same basic reaction conditions led to partial epimerization (10–15%) at C-6 of ketone **28** rendering an inseparable mixture of alcohols.



Scheme 5.

Fortunately, with freshly prepared samarium diiodide, the undesirable epimerization at C-6 could be suppressed.[30] Clean reduction to the two chromatographically inseparable, epimeric alcohols **27**/**29** in 1.6:1 ratio was attained.

With aged samarium diiodide, the rate of reduction decreased considerably. Here, next to the two alcohols **27** and **29**, unconsumed ketone **28** contaminated with one epimeric ketone (**i**) was isolated. To gain insight into the regiochemistry of this epimerization, the inseparable mixture of the ketones was reduced with half an equivalent of lithium Selectride mainly yielding one alcohol (**ii**), which was characterized as its triethylsilyl ether **33** permitting comparison with the analogous hydrindene derivative with the methyl group at C-8 in the *endo* position.[28] These data revealed that the epimerization had occurred at C-6, rendering the *trans*-hydrindene system (Scheme 6).



Scheme 6.

The chromatographically inseparable mixture of alcohols **27** and **29** was treated with iodine under basic conditions[31] thereby converting the *endo* alcohol **27** to the tricyclic iodide **30**. Easy chromatographic separation yielded the desired alcohol **29**. Alcohol **27** was regenerated by treatment of **30** with zinc in acetic acid and could be recycled. Hydrindenol **29** was acetylated to **31** and the primary hydroxy group was deprotected with bromodimethylborane[32] yielding **32** as starting material for the projected combination of the hydrindene subunit with the lactone subunit.

4. Conclusion

In this report we describe two approaches to the hydrindenol subunit of the cochleamycins. In both pathways, intermolecular Diels–Alder reaction, selective methylation, acidic fragmentation, Shapiro reaction and inversion by oxidation/reduction sequence were the key steps. Comparison of the two pathways (Schemes 2, 4, and 5) starting with ketone **1** up to the protected *exo* alcohols **23** and **31** reveals that the advantage gained in the latter, conducted as EPC-synthesis, by reducing the amount of steps is offset by separation problems. Thus the originally designed route, conducted here as a racemic synthesis, is preferable.

5. Experimental section

5.1. General

^{1}H and ^{13}C NMR spectra were recorded on a Bruker Spectrospin AM 400-WB. Residual, non-deuterated solvent served as internal reference for ^{1}H spectra. For ^{13}C spectra, chemical shifts are given relative to the 77.00 ppm signal of $CDCl_3$. Coupling constants are given in Hertz. Optical rotations were measured on a Perkin–Elmer 241 polarimeter with the Na D-line. IR spectra were recorded on a Perkin–Elmer 1600 FTIR spectrometer and given in wave numbers (cm^{-1}). Melting points were obtained using a Reichert 'Kofler' hot stage microscope and are uncorrected. EI mass spectra were recorded on a Finnigan 8230 spectrometer. Unless otherwise stated, starting materials were purchased from commercial suppliers and used without further purification. Dry dichloromethane was distilled from P_2O_5 and kept over 4 Å molecular sieves. Dry THF was distilled under argon from Na/benzophenone prior to use. Silica gel (230–400 mesh ASTM, Merck) was used for flash chromatography.

5.2. (±)-(1*S**,2*S**,6*S**,7*R**)-1,7,8,9-Tetrachloro-10,10-dimethoxytricyclo[5.2.1.0^{2,6}]dec-8-en-3-one (1)[17a] and (±)-(1*S**,2*S**,6*S**,7*R**)-1,7,8,9-tetrachloro-10,10-dimethoxytricyclo[5.2.1.0^{2,6}]dec-8-en-4-one (2)

Cyclopent-2-enone (4.2 g, 51.2 mmol), 2,3,4,5-tetrachloro-1,1-dimethoxycyclopenta-2,4-diene (13.5 g, 51.1 mmol) and a trace amount of dihydrobenzo-1,4-quinone were heated under argon in a sealed tube at 115 °C for 90 h. The reaction mixture was purified by flash chromatography (petroleum ether/diethyl ether 7:1) yielding **1**[17a] (11.55 g, 65.3%) and **2** (2.95 g, 16.7%) as white crystals. Mp=113–115 °C. IR (cm^{-1}, CCl_4): 2958, 2927, 2855, 1752, 1602, 1460; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 2.22 (m, 2H, H (5*endo*,3*endo*), $J_{3endo,3exo}$=$J_{5endo,5exo}$=19.5 and long range couplings), 2.37 (m, 2H, H(5*exo*,3*exo*), $J_{3exo,3endo}$=$J_{5exo,5endo}$=19.5, $J_{3,2}$~$J_{5,6}$~7.8 and several long range couplings), 3.35 (m, 2H, H(2,6), $J_{2,3}$=$J_{5,6}$=7.8 and several long range couplings), 3.55 (s, 3H, OCH_3), 3.63 (s, 3H, OCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 37.3, 47.8, 52.2, 53.0, 78.2, 113.4, 130.5, 212.6; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=348/346/344 (0.35/0.54/0.45, M^+), 313/311/309 (30/97/100, M^+-Cl); HRMS (EI, 70 eV, 50 °C) calcd for $C_{12}H_{12}{}^{35}Cl_4O_3$ (M^+): 345.9512, found: 345.9501; Anal. Calcd for $C_{12}H_{12}Cl_4O_3$: C=41.65%, H=3.50%, found: C=41.58%, H=3.57%.

5.3. (1*S*,2*S*,4*S*,6*S*,7*R*)-1,7,8,9-Tetrachloro-10,10-dimethoxy-4-methyltricyclo[5.2.1.0^{2,6}]dec-8-en-3-one (3)

At −78 °C, LiHMDS (42 mL, 1 M solution in THF, 42 mmol) and HMPTA (25 mL) were added to dry THF (260 mL). A solution of (+)-**1** (12.0 g, 34.7 mmol) in dry THF (50 mL) was added slowly and the mixture was stirred at −78 °C for 1 h. CH_3I (2.2 mL, 35.0 mmol) was added dropwise to the mixture, which was allowed to warm to room temperature over 16 h. The reaction was quenched with aq acetic acid (100 mL, 1:1) and extracted four times with toluene. The combined organic layers were washed with water, satd aq $NaHCO_3$ and brine, and dried over $MgSO_4$. The solvent was removed by rotary evaporation and the crude product was purified by flash chromatography on silica gel (petroleum ether/diethyl ether 8:1) affording **3** as white crystals (10.2 g, 82%). $[\alpha]_D^{20}$ +135.7 (*c* 1.0, $CHCl_3$). Mp=120–124 °C. IR (cm^{-1}, film): 2986, 2973, 2951, 1736, 1599, 1456, 1252, 1190, 1157, 1133; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 1.01 (d, 3H, C(4)CH_3, $J_{CH_3,4}$=7), 1.57 (ddd, 1H, H(5*exo*), $J_{5exo,4}$=11, $J_{5endo,5exo}$=14.6, $J_{5exo,6}$=10), 1.94 (m, 1H, H(4), $J_{4,5exo}$=11,

$J_{4,5endo}$=10.4, J_{4,CH_3}=7), 2.25 (ddd, 1H, H(5*endo*), $J_{5endo,4}$=10.4, $J_{5endo,5exo}$=14.6, $J_{5endo,6}$=1.3), 3.10 (d, 1H, H(2), $J_{2,6}$=9), 3.25 (ddd, 1H, H(6), $J_{6,2}$=9, $J_{6,5exo}$=10, $J_{6,5endo}$=1.5), 3.52 (s, 3H, OCH_3), 3.57 (s, 3H, OCH_3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.1, 28.3, 43.2, 46.7, 51.7, 52.6, 57.6, 76.1, 77.6, 114.1, 128.8, 129.3, 214.9; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=345 (1), 311 (40), 309 (100), 307 (98); HRMS (EI, 70 eV, 40 °C) calcd for $C_{13}H_{14}{}^{35}Cl_3O_3$ $(M-{}^{35}Cl)^+$: 323.0008, found: 323.0017.

5.4. (1*S*,2*S*,4*S*,6*S*,7*R*)-4-Methyl-1,7,8,9-tetrachloro-10,10-dimethoxytricyclo[5.2.1.0^{2,6}]dec-8-en-3-ol (4)

Compound (+)-**3** (13.7 g, 38.1 mmol) was dissolved in methanol (540 mL) and cooled to 0 °C. $NaBH_4$ (3.58 g, 94.7 mmol) was added and the mixture was stirred at room temperature for 1 h. The reaction was quenched with satd aq NH_4Cl (20 mL), reduced to approx. 1/2 volume by rotary evaporation and extracted with dichloromethane (4×80 mL). The combined organic layers were dried over $MgSO_4$ and evaporated to dryness. The crude product was purified on silica gel (petroleum ether/diethyl ether 3:1) and isolated as white crystals (13.4 g, 97%). $[\alpha]_D^{20}$ −18.1 (*c* 1.0, $CHCl_3$). Mp=60–64 °C. IR (cm^{-1}, film): 3589, 3488br, 2952, 1454, 1190; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.96 (d, 3H, C(4)CH_3, $J_{CH_3,4}$=6.3), 1.19 (ddd, 1H, H(5*exo*), $J_{5exo,4}$=11.6, $J_{5endo,5exo}$=14.5, $J_{5exo,6}$=9.5), 1.60 (m, 1H, H(4), $J_{4,5exo}$=11.6, $J_{4,5endo}$=8, $J_{4,3}$=9.7, J_{4,CH_3}=6.3), 1.64 (d, 1H, OH, $J_{OH,3}$=5.7), 1.81 (ddd, 1H, H(5*endo*), $J_{5endo,4}$=8, $J_{5endo,5exo}$=14.5, $J_{5endo,6}$=1.3), 2.99 (ddd, 1H, H(6), $J_{6,2}$=8.5, $J_{6,5exo}$=9.5, $J_{6,5endo}$=1.5), 3.19 (t, 1H, H(2), $J_{2,6}$=$J_{2,3}$=8.5), 3.51 (s, 3H, OCH_3), 3.56 (s, 3H, OCH_3), 3.81 (ddd, 1H, H(3), $J_{3,2}$=8.6, $J_{3,4}$=9.7, $J_{3,OH}$=5.7); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.7, 29.8, 40.2, 51.4, 51.5, 52.5, 54.9, 76.6, 77.6, 80.5, 114.5, 128.9, 129.8; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=331 (4), 330 (5), 329 (29), 328 (13), 327 (91), 326 (14), 325 (100), 295 (4), 293 (5), 291 (3), 259 (4), 257 (19), 255 (51), 253 (59), 211 (6), 209 (17), 207 (17), 75 (50), 59 (40); HRMS (EI, 70 eV, 30 °C) calcd for $C_{13}H_{16}{}^{35}Cl_4O_3$ $(M-{}^{35}Cl)^+$: 359.9854, found: 359.9866.

5.5. (1*R*,3*S*,5*S*,7*S*,8*R*,9*S*,11*S*)-3-Ethoxy-6,6-dimethoxy-11-methyl-2-oxatetracyclo[6.3.0.0^{3,7}.0^{5,9}]undecane (5)

Dry ethanol (480 mL) was placed in a three-necked round-bottomed flask equipped with a Liebig condenser, dropping funnel and a mechanical stirrer. Sodium (3.0 g, 131 mmol) was added and the flask was heated to reflux until the sodium was dissolved. A solution of (−)-**4** (11.9 g, 32.9 mmol) in dry ethanol (180 mL) was then added slowly over 30 min. After 1 h at reflux, additional sodium (37.4 g, 1.62 mol) was added in small pieces over 1.5 h, while continuing to reflux. After a further 1.5 h, another portion of sodium (4.0 g, 174 mmol) was added. After a further 2 h, at reflux the mixture was cooled and poured on ice. Satd aq NH_4Cl (200 mL) was added and the solution was extracted with dichloromethane (4×200 mL). The combined organic layers were washed with brine, dried over $MgSO_4$ and evaporated under reduced pressure. The crude product was purified on silica gel (petroleum ether/diethyl ether 4:1) and isolated as oil (7.95 g, 90%). $[\alpha]_D^{20}$ +0.5 (*c* 1.0, $CHCl_3$). IR (cm^{-1}, film): 2959, 2830,1329, 1289, 1148; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.79 (d, 3H, C(11)CH_3, $J_{CH_3,11}$=7.5), 1.18 (t, 3H, H(2′), $J_{2',1'}$=7), 1.32 (dd, 1H, H(10*exo*), $J_{10exo,10endo}$=13.8, $J_{10exo,9}$=9.6), 1.73 (ddd, 1H, H(10*endo*), $J_{10endo,11}$=7.7, $J_{10endo,10exo}$=13.6, $J_{10endo,9}$=4.8), 1.85 (m, 1H, H(4*endo*), $J_{4endo,4exo}$=13.6, $J_{4endo,5}$=1.9), 2.10 (m, 2H, H(4*exo*), H(5), $J_{4exo,4endo}$=13.4, $J_{4exo,5}$=3.8, $J_{4,9}$=1.6, $J_{5,4exo}$=3.8, $J_{5,9}$=4.7, $J_{5,4endo}$=1.8, $J_{5,7}$=1.3), 2.30 (quin., 1H, H(11), $J_{11,10endo}$=J_{11,CH_3}=7.5), 2.60 (dd, 1H, H(7), $J_{7,8}$=5.1, $J_{7,5}$=1.3), 2.78 (m, 1H, H(9), $J_{9,10exo}$=$J_{9,8}$=9.6, $J_{9,10endo}$=$J_{9,5}$=4.8, $J_{9,4}$=1.4), 2.68 (m, 1H, H(8), $J_{8,1}$=$J_{8,7}$=4–5, $J_{8,9}$=9.6), 3.22 (s, 3H, OCH_3), 3.23 (s, 3H, OCH_3), 3.50 (A-part of ABX_3-system, 1H, H(1′), $J_{1',2'}$=7.1, $J_{1',1'}$=9.2), 3.65 (B-part of ABX_3-system, 1H, H(1′), $J_{1',2'}$=7.1, $J_{1',1'}$=9.2), 4.01 (d, 1H, H(1), $J_{1,8}$=4); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.6, 19.4, 31.1, 37.9, 40.8, 41.9, 42.6, 48.5, 49.3, 50.0, 50.6, 58.8, 86.2, 113.6, 116.4; MS (EI, 70 eV, 20 °C): *m*/*z* (%)=268 (2), 253 (35), 236 (100), 223 (61), 195 (26), 158 (49), 131 (63), 88 (50); HRMS (EI, 70 eV, 20 °C) calcd for $C_{15}H_{24}O_4$ $(M)^+$: 268.1675, found: 268.1669; Anal. Calcd for $C_{15}H_{24}O_4$: C=67.14%, H=9.01%, found: C=67.27%, H=9.19%.

5.6. (1*S*,2*S*,6*S*,7*R*,8*S*)-7-Hydroxy-8-methyl-4-oxobicyclo[4.3.0]non-2-yl-carboxylic acid (6)

Compound (+)-**5** (8.46 g, 31.5 mmol) was dissolved in a mixture of dioxane (140 mL) and 3% aq HCl (92 mL), and heated to reflux for 5 h. The solution was then diluted with water (50 mL) and extracted with ethyl acetate (4×100 mL, 4×50 mL). The combined organic layers were washed with brine (100 mL) and dried over $MgSO_4$. The solvent was evaporated to afford 8.19 g of a brown oil, which was used without further purification. Mp=141 °C (racemic). IR (cm^{-1}, film): 3401–2700, 2956, 1713; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.79 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 1.38 (dt, 1H, H(9β), $J_{9\beta,1}$=$J_{9\beta,8}$=7.2, $J_{9\beta,9\alpha}$=12.7), 1.78 (ddd, 1H, H(9α), $J_{9\alpha,1}$=4.2, $J_{9\alpha,8}$=7.5, $J_{9\alpha,9\beta}$=12.6), 1.95 (m, 1H, H(8), $J_{8,9\alpha}$∼$J_{8,9\beta}$∼7.4, J_{8,CH_3}=6.9, $J_{8,7}$=4.6), 2.19 (m, 2H, H(5), H(3β)), 2.38 (m, 4H, H(3α), H(1), H(5), H(6)), 2.75 (ddd, 1H, H(2), $J_{2,1}$=10.6, $J_{2,3\beta}$=8.7, $J_{2,3\alpha}$=4.4), 3.55 (t, 1H, H(7), $J_{7,8}$=$J_{7,6}$=4.6), 4.8 (br s, 1H, OH), 12.3 (br s, 1H, COOH); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.15, 35.9, 37.0, 37.5, 39.1, 39.9, 40.3, 44.0, 79.4, 175.6, 210.5; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=212 (4), 194 (56), 166 (33), 139 (61), 107 (39), 95 (63), 81 (38), 55 (49).

5.7. (1*S*,2*S*,6*S*,7*R*,8*S*)-Methyl 7-hydroxy-8-methyl-4-oxobicyclo[4.3.0]non-2-yl-carboxylate (7)

Crude **6** (ca. 31.5 mmol) was dissolved in diethyl ether (200 mL) at 0 °C. Diazomethane in diethyl ether was added until the yellow colour remained, whereupon it was allowed to stir for a further 1 h, while warming to room temperature. A few drops of acetic acid were added to destroy any remaining diazomethane, then the solvent was removed by rotary evaporation. The residue was purified on silica gel (petroleum ether/ethyl acetate 1:1) yielding a viscous, yellowish oil, which slowly solidified on standing (6.41 g, 90% over two steps). $[\alpha]_D^{20}$ +116.6 (*c* 1.4, $CHCl_3$). Mp=46 °C (racemic: 87 °C). IR (cm^{-1}, film): 3436, 2954, 1716, 1272, 1196, 1172; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.98 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.0), 1.50 (ddd, 1H, H(9β),

$J_{9\beta,1}$=6.4, $J_{9\beta,8}$=7.5, $J_{9\beta,9\alpha}$=13.6), 1.88 (ddd, 1H, H(9α), $J_{9\alpha,1}$=4.1, $J_{9\alpha,8}$=7.6, $J_{9\alpha,9\beta}$=13.5), 2.10 (m, 1H, H(8), $J_{8,9\alpha}$~$J_{8,9\beta}$~J_{8,CH_3}~7–7.5, $J_{8,7}$=3.8), 2.39 (dd, 1H, H(3β), $J_{3\beta,3\alpha}$=17.0, $J_{3\beta,2}$=11.0), 2.4–2.6 (m, 4H, H(5α), H(5β), H(1), H(6)), 2.53 (dd, 1H, H(3α), $J_{3\alpha,3\beta}$=17.0, $J_{3\alpha,2}$=4.4), 2.93 (ddd, 1H, H(2), $J_{2,1}$=9.4, $J_{2,3\beta}$=11.0, $J_{2,3\alpha}$=4.5), 3.68 (s, 3H, OCH_3), 3.78 (dd, 1H, H(7), $J_{7,8}$=4, $J_{7,6}$=4.7), 4.72 (br s, 1H, OH); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.4, 36.3, 37.8, 37.9, 40.6, 40.8, 40.9, 44.7, 52.0, 81.1, 174.7, 211.2; MS (EI, 70 eV, 30 °C): *m/z* (%)=226 (24), 208 (25), 194 (46), 167 (30), 139 (100), 121 (46), 107 (65), 95 (55), 79 (42), 67 (36), 55 (52); HRMS (EI, 70 eV, 70 °C) calcd for $C_{12}H_{18}O_4$ $(M)^+$: 226.1205, found: 226.1214; Anal. Calcd for $C_{12}H_{18}O_4$: C=63.70%, H=8.02%, found: C=63.89%, H=8.15%.

5.8. (±)-(1*R**,2*S**,8*S**)-Methyl 8-methyl-4-oxobicyclo-[4.3.0]non-5-ene-2-carboxylate (8) and (±)-(1*S**,2*S**,6*S**,7*S**,8*S**)-methyl 8-methyl-7-(4-nitrobenzoyloxy)-4-oxobicyclo[4.3.0]nonane-2-carboxylate (9)

To a stirred solution of **7** (180 mg, 0.8 mmol) in dry benzene (9 mL) were added under argon triphenylphosphine (350 mg, 1.3 mmol) and 4-nitrobenzoic acid (250 mg, 1.5 mmol). After 20 min, diethyl azodicarboxylate (0.2 mL, 1.6 mmol) was added dropwise to the reaction mixture, which was then stirred for 4 h at room temperature. The reaction was quenched with satd aq NH_4Cl and extracted with toluene (4×). The combined organic layers were washed with satd aq $NaHCO_3$, aq K_2CO_3 and brine, and dried over $MgSO_4$. The solvent was removed under reduced pressure. The products were first separated on Al_2O_3 90 (according to Brockmann, petroleum ether/ethyl acetate 4:1) and then on silica gel (petroleum ether/ethyl acetate 4:1) giving **8** (70 mg, 42%) as a colourless oil and **9** (24 mg, 8%) as white crystals. Data for **8**: IR (cm^{-1}, film): 2956, 1737, 1670, 1277, 1239, 1172; ^{1}H NMR (400 MHz, C_6D_6) δ (ppm) 0.70 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.0), 1.21 (ddd, 1H, H(9β), $J_{9\alpha,9\beta}$=12.7, $J_{9\beta,1}$=9.8, $J_{9\beta,8}$=7.8), 1.58 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=12.5, $J_{9\alpha,8}$=3.5, $J_{9\alpha,1}$=8.8), 1.67 (m, 1H, H(7β), $J_{7\beta,7\alpha}$=17.4, $J_{7\beta,8}$=4.4), 1.77 (m, 1H, H(8)), 2.08 (ddt, 1H, H(7α), $J_{7\alpha,7\beta}$=17.7, $J_{7\alpha,8}$=7.3, $J_{7\alpha,5}$=$J_{7\alpha,1}$=1.5), 2.33 (m, 3H, H(3α), H(3β), H(2)), 2.70 (q, 1H, H(1), $J_{1,2}$=$J_{1,9\alpha}$=$J_{1,9\beta}$=8.5–9), 3.29 (s, 3H, OCH_3), 5.79 (m, 1H, H(5), $J_{5,1}$~$J_{5,7\alpha}$~$J_{5,7\beta}$~1.3); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.1, 31.0, 37.8, 39.8, 40.4, 41.9, 46.9, 51.9, 121.8, 172.8, 173.3, 196.8; MS (EI, 70 eV, 30 °C): *m/z* (%)=208 (13), 149 (100), 122 (13), 107 (37), 91 (9), 79 (18), 65 (3), 55 (6), 41 (5). Data for **9**: mp=95 °C. IR (cm^{-1}, film): 2955, 1718, 1607, 1528, 1349, 1276, 1103; ^{1}H NMR (400 MHz, C_6D_6) δ (ppm) 0.78 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 0.92 (dt, 1H, H(9β), $J_{9\alpha,9\beta}$=13.3, $J_{9\beta,1}$=$J_{9\beta,8}$=7.1), 1.44 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=13.2, $J_{9\alpha,8}$=4.5, $J_{9\alpha,1}$=7.1), 1.67 (dd, 1H, H(5α), $J_{5\alpha,5\beta}$=15.6, $J_{5\alpha,6}$=12.2), 1.94 (m, 1H, H(8), J_{8,CH_3}=$J_{8,9\beta}$=7, $J_{8,7}$=$J_{8,9\alpha}$=4.2–4.5), 2.05 (dddd, 1H, H(6), $J_{6,7}$=4, $J_{6,5\beta}$=5.7, $J_{6,5\alpha}$=12.4, $J_{6,1}$=10), 2.14 (dd, 1H, H(3β), $J_{3\beta,3\alpha}$=16.8, $J_{3\beta,2}$=12.0), 2.24 (dt, 1H, H(2), $J_{2,3\beta}$=$J_{2,1}$=10–12, $J_{2,3\alpha}$=3.5), 2.33 (dd, 1H, H(5β), $J_{5\beta,5\alpha}$=15.4, $J_{5\beta,6}$=5.7), 2.35 (dd, 1H, H(3α), $J_{3\alpha,3\beta}$=16.8, $J_{3\alpha,2}$=3.5), 2.42 (m, 1H, H(1), $J_{1,9\alpha}$=4.4, $J_{1,6}$=$J_{1,9\beta}$=$J_{1,2}$=7–10), 3.32 (s, 3H, OCH_3), 4.78 (t, 1H, H(7), $J_{7,6}$~$J_{7,8}$~4.2), 7.75 (s, 4H(aryl)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.7, 34.9, 36.9, 37.4, 40.6, 40.7, 41.5, 43.3, 52.2, 84.2, 123.6, 130.6, 135.4, 150.6, 164.2, 173.9, 208.6; MS (EI, 70 eV, 30 °C): *m/z* (%)=294 (17), 279 (78), 208 (63), 193 (100), 150 (95), 120 (46), 104 (32), 92 (16), 79 (16), 55 (17), 41 (11).

5.9. (±)-(1*S**,2*S**,6*S**,7*R**,8*S**)-Methyl 8-methyl-7-(4′-nitrobenzoyloxy)-4-oxobicyclo[4.3.0]non-2-yl-carboxylate (10)

A solution of **7** (30 mg, 132 μmol) in dry pyridine (1 mL) was treated with *p*-nitrobenzoyl chloride (120 mg, 0.65 mmol) and stirred for 16 h at room temperature. The reaction was quenched with water and acidified with concd HCl. The mixture was extracted with toluene (4×). The combined organic layers were washed with water, satd aq $NaHCO_3$, aq K_2CO_3 and brine. The organic solution was dried ($MgSO_4$) and the solvent was removed under reduced pressure. The crude product was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 3:1) to give 35 mg (71%) of the product as white crystals. Mp=93 °C. IR (cm^{-1}, film): 2957, 1723, 1529, 1349, 1274, 1102; ^{1}H NMR (400 MHz, C_6D_6) δ (ppm) 0.87 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.0), 1.13 (dt, 1H, H(9β), $J_{9\alpha,9\beta}$=13.5, $J_{9\beta,1}$=$J_{9\beta,8}$=7.5), 1.72 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=13.6, $J_{9\alpha,8}$=8.0, $J_{9\alpha,1}$=3.2), 1.9–2.1 (m, 4H, H(5α), H(5β), H(6), H(8)), 2.2–2.3 (m, 2H, H(3β), H(1)), 2.48 (dd, 1H, H(3α), $J_{3\alpha,3\beta}$=15.8, $J_{3\alpha,2}$=4.2), 2.70 (ddd, 1H, H(2), $J_{2,3\beta}$=12.1, $J_{2,1}$=10.8, $J_{2,3\alpha}$=4.2), 3.32 (s, 3H, OCH_3), 4.72 (dd, 1H, H(7), $J_{7,6}$=5.9, $J_{7,8}$=3.5), 7.75 (s, 4H(aryl)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.7, 36.5, 37.7, 38.8, 38.9, 40.7, 41.2, 44.6, 52.2, 85.1, 123.6, 130.6, 135.2, 150.6, 164.3, 173.9, 208.7; MS (EI, 70 eV, 30 °C): *m/z* (%)=343 (7), 208 (41), 193 (28), 150 (100), 137 (12), 120 (32), 104 (28), 92 (12), 76 (11), 55 (7), 41 (5).

5.10. (1*S*,3*S*,4*S*,6*S*,7*R*,8*S*)-Methyl [1-(*tert*-butyldimethylsiloxy)-6-methyl-10-oxatricyclo[5.2.1.0^{4,8}]dec-3-yl]carboxylate (11)

Compound (+)-**7** (5.43 g, 24.0 mmol) was dissolved in dry dichloromethane (750 mL) containing triethylamine (10.0 mL, 72.0 mmol) and the solution was cooled to −50 °C. TBSOTf (7.2 mL, 31.2 mmol) was added slowly by syringe. After 30 min, the reaction was quenched with satd aq NH_4Cl (100 mL). The aqueous layer was extracted with diethyl ether (3×90 mL) and the combined organic layers were washed with satd aq $NaHCO_3$ (200 mL) and brine (200 mL), and dried over $MgSO_4$. The solvent was removed by rotary evaporation and the crude product was purified on silica gel (petroleum ether/ethyl acetate 20:1) to afford **11** (8.0 g, 98%) as a colourless oil. $[\alpha]_D^{20}$ −8.8 (*c* 1.0, $CHCl_3$). IR (cm^{-1}, film): 2955, 1735, 1462, 1342, 1248, 1178; ^{1}H NMR (400 MHz, C_6D_6) δ (ppm) 0.25 (s, 3H, $SiCH_3$), 0.30 (s, 3H, $SiCH_3$), 0.62 (d, 3H, C(6)CH_3, $J_{CH_3,6}$=7.3), 1.03 (s, 9H, $C(CH_3)_3$), 1.30 (ddd, 1H, H(5β), $J_{5\beta,5\alpha}$=13.1, $J_{5\beta,4}$=8.2, $J_{5\beta,6}$=4.1), 1.66 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=11.5, $J_{9\alpha,8}$=3.6, $J_{9\alpha,2\alpha}$=2.5), 1.67 (ddd, 1H, H(5α), $J_{5\alpha,5\beta}$=13.3, $J_{5\alpha,6}$=7.7, $J_{5\alpha,4}$~4), 1.92 (d, 1H, H(9β), $J_{9\beta,9\alpha}$=11.7), 2.10 (quin.d, 1H, H(6), J_{6,CH_3}=7.3, $J_{6,5\alpha}$~7, $J_{6,5\beta}$=4.2), 2.20 (ddd, 1H, H(2α), $J_{2\alpha,2\beta}$=13, $J_{2\alpha,3}$=9.6, $J_{2\alpha,9\alpha}$=2.1), 2.27 (dt, 1H, H(3), $J_{3,2\alpha}$=9.6, $J_{3,2\beta}$=$J_{3,4}$=3.5), 2.28 (ddd, 1H, H(8), $J_{8,4}$=11.6, $J_{8,9\alpha}$=3.5, $J_{8,7}$=3.3), 2.54 (dd, 1H, H(2β), $J_{2\alpha,2\beta}$=13.4, $J_{2\beta,3}$=3.4), 2.72 (ddt, 1H, H(4), $J_{4,8}$=11.6, $J_{4,5\beta}$=8.0, $J_{4,5\alpha}$=4.0, $J_{4,3}$=3.5), 3.31 (s, 3H, OCH_3), 3.86 (d, 1H, H(7), $J_{7,8}$=3.3); ^{13}C NMR (100 MHz,

$CDCl_3$) δ −3.1, −2.9, 17.6, 18.5, 25.8, 37.3, 37.9, 38.0, 40.4, 41.1, 43.6, 44.8, 51.7, 89.3, 105.9, 176.5; MS (EI, 70 eV, 30 °C): *m/z* (%)=340 (18), 283 (100), 225 (40), 151 (28), 131 (17), 73 (57), 107 (65); HRMS (EI, 70 eV, 40 °C) calcd for $C_{18}H_{32}O_4$ $(M)^+$: 340.2070, found: 340.2084; Anal. Calcd for $C_{18}H_{32}O_4$: C=63.49%, H=9.47%, found: C=63.75%, H=9.71%.

5.11. (1*R*,3*S*,4*R*,6*S*,7*R*,8*S*)-1-(*tert*-Butyldimethylsiloxy)-3-(hydroxymethyl)-6-methyl-10-oxatricyclo[5.2.1.0^{4,8}]-decane (12)

$LiAlH_4$ (0.99 g, 26.0 mmol) was suspended in dry diethyl ether (50 mL). A solution of (−)-**11** (8.0 g, 23.5 mmol) in dry diethyl ether (20 mL) was added slowly by syringe and the mixture was stirred at room temperature. After 3 h, satd aq NH_4Cl (50 mL) was added and the phases were separated. The aqueous layer was extracted with diethyl ether (4×50 mL). The combined organic layers were washed with brine (3×50 mL) and dried over $MgSO_4$. The solution was then evaporated to dryness to give the analytically pure product as white crystals (7.3 g, 99%). $[\alpha]_D^{20}$ +10.0 (*c* 1.0, $CHCl_3$). Mp=48–50 °C. IR (cm^{-1}, film): 3355, 2954, 2857, 1472; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.09 (s, 3H, $SiCH_3$); 0.10 (s, 3H, $SiCH_3$), 0.85 (s, 9H, $C(CH_3)_3$), 0.95 (d, 3H, C(6)CH_3, $J_{CH_3,6}$=7.3), 1.27 (ddd, 1H, H(5β), $J_{5\alpha,5\beta}$=13.5, $J_{5\beta,4}$=8.0, $J_{5\beta,6}$=5.4), 1.54 (dd, 1H, H(2α), $J_{2\alpha,2\beta}$=13.0, $J_{2\alpha,3}$=8.1), 1.74–1.96 (m, 7H, H(2β), H(3), H(4), H(5α), H(9α), H(9β), OH), 2.28 (sextett, 1H, H(6), J_{6,CH_3}∼$J_{6,5}$∼$J_{6,5}$∼7.5), 2.49 (ddt, 1H, H(8), $J_{8,4}$=7.8, $J_{8,7}$=4.0, $J_{8,9\alpha}$=$J_{8,9\beta}$=1.5–2), 3.48 (dd, 1H, H(1′), $J_{1',1}$=10.4, $J_{1',3}$=6.6), 3.52 (dd, 1H, H(1′), $J_{1',1}$=10.4, $J_{1',3}$=6.1), 4.03 (d, 1H, H(7), $J_{7,8}$=4.0); ^{13}C NMR (100 MHz, $CDCl_3$) δ −2.9, −2.8, 17.8, 19.4, 25.9, 38.8, 39.3, 39.6, 41.8, 42.0, 44.3, 46.9, 67.9, 90.5, 106.5; MS (EI, 70 eV, 50 °C): *m/z* (%)=312 (13), 281 (11); 255 (100), 225 (53), 197 (6), 163 (15), 145 (34), 121 (18), 75 (86); HRMS (EI, 70 eV, 50 °C) calcd for $C_{13}H_{23}O_3Si$ $(M-t\text{-}Bu)^+$: 255.1416, found: 255.1399; Anal. Calcd for $C_{17}H_{32}O_3Si$: C=65.33%, H=10.32%, found: C=65.39%, H=10.14%.

5.12. (1*R*,3*S*,4*S*,6*S*,7*R*,8*S*)-1-(*tert*-Butyldimethylsiloxy)-3-(2,4-dioxapentyl)-6-methyl-10-oxatricyclo[5.2.1.0^{4,8}]-decane (13)

Compound (+)-**12** (7.3 g, 23.4 mmol) was dissolved in dry dichloromethane (300 mL). Hünig's base (20.0 mL, 117 mmol) was added, followed by MOMCl (5.3 mL, 70.3 mmol). After 3 h at room temperature, the reaction was quenched with satd aq NH_4Cl (100 mL). The aqueous phase was extracted with dichloromethane (4×100 mL) and the combined organic layers were washed with satd aq $NaHCO_3$ (100 mL) and brine (100 mL), and dried over $MgSO_4$. The solvent was removed under reduced pressure and the crude product was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate 10:1). The product was obtained as a colourless oil (8.2 g, 98%). $[\alpha]_D^{20}$ +12.2 (*c* 1.0, $CHCl_3$). IR (cm^{-1}, film): 2954, 2857, 1250; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.10 (s, 3H, $SiCH_3$); 0.11 (s, 3H, $SiCH_3$), 0.86 (s, 9H, $C(CH_3)_3$), 0.96 (d, 3H, C(6)CH_3, $J_{CH_3,6}$=7.3), 1.27 (ddd, 1H, H(5β), $J_{5\alpha,5\beta}$=13.0, $J_{5\beta,4}$=8.0, $J_{5\beta,6}$=5.4), 1.58 (dd, 1H, H(2α), $J_{2\alpha,2\beta}$=12.3, $J_{2\alpha,3}$=7.2), 1.78–1.96 (m, 6H, H(2β), H(3), H(4), H(5α), H(9α), H(9β)), 2.29 (sextett, 1H, H(6), J_{6,CH_3}∼$J_{6,5}$∼$J_{6,5}$∼7.5), 2.49 (m, 1H, H(8)), 3.35 (s, 3H, CH_3O), 3.39 (dd, 1H, H(1′), $J_{1',1'}$=9.2, $J_{1',3}$=6.1), 3.42 (dd, 1H, H(1′), $J_{1',1'}$=9.3, $J_{1',3}$=5.5), 4.03 (d, 1H, H(7), $J_{7,8}$=4.0), 4.60 (s, 2H, OCH_2O); ^{13}C NMR (100 MHz, $CDCl_3$) δ −2.9, −2.8, 17.8, 19.4, 25.9, 38.8, 39.5, 39.6, 39.8, 42.3, 44.2, 47.0, 55.2, 73.0, 90.5, 96.5, 106.6; MS (EI, 70 eV, 30 °C): *m/z* (%)=356 (2), 299 (67), 281 (15); 267 (19), 253 (25), 241 (4), 225 (34), 175 (30), 145 (30), 121 (30), 93 (32), 73 (100); HRMS (EI, 70 eV, 40 °C) calcd for $C_{19}H_{36}O_4Si$ $(M)^+$: 356.2383, found: 356.2377; Anal. Calcd for $C_{19}H_{36}O_4Si$: C=64.00%, H=10.18%, found: C=64.18%, H=10.27%.

5.13. (1*R*,2*S*,6*S*,7*R*,8*S*)-2-(2,4-Dioxapentyl)-7-hydroxy-8-methylbicyclo[4.3.0]nonan-4-one (14)

Compound (+)-**13** (7.8 g, 21.9 mmol) was dissolved in dry THF (350 mL) and TBAF (43.8 mL, 1 M solution in THF, 43.8 mmol) was added. After 1.5 h, the solution was diluted with water (100 mL) and the layers were separated. The aqueous layer was extracted with diethyl ether (4×100 mL) and ethyl acetate (100 mL), and the combined organic layers were washed with satd aq $NaHCO_3$ (100 mL) and brine (100 mL), and dried over $MgSO_4$. The product was purified on silica gel (petroleum ether/ethyl acetate 1:1) and isolated as white crystals (5.0 g, 94%). $[\alpha]_D^{20}$ +157.1 (*c* 1.0, $CHCl_3$). Mp=57–58 °C. IR (cm^{-1}, film): 3462, 2950, 2825, 1710, 1458; ^1H NMR (400 MHz, C_6D_6) δ (ppm) 0.82 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 1.16 (ddd, 1H, H(9β), $J_{9\beta,1}$=8.2, $J_{9\beta,8}$=6.7, $J_{9\beta,9\alpha}$=13.0), 1.63 (ddd, 1H, H(9α), $J_{9\alpha,1}$=5.0, $J_{9\alpha,8}$=7.7, $J_{9\alpha,9\beta}$=12.9), 1.77 (m, 1H, H(1), $J_{1,9a}$∼$J_{1,6}$∼$J_{1,2}$∼8.5–10, $J_{1,9\beta}$=5.0), 1.80–1.94 (m, 2H, H(2), H(8)), 2.02 (dd, 1H, H(3β), $J_{3\beta,3\alpha}$=16.4, $J_{3\beta,2}$=11.6), 2.04 (m, 1H, H(6), $J_{6,7}$∼$J_{6,5\beta}$∼6, $J_{6,5\alpha}$∼$J_{6,1}$∼9), 2.20 (br s, 1H, OH), 2.27 (dd, 1H, H(5β), $J_{5\beta,5\alpha}$=15.4, $J_{5\beta,6}$=6.3), 2.37 (dd, 1H, H(5α), $J_{5\alpha,5\beta}$=15.4, $J_{5\alpha,6}$=9.7), 2.46 (dd, 1H, H(3α), $J_{3\alpha,3\beta}$=16.6, $J_{3\alpha,2}$=3.8), 3.13 (s, 3H, CH_3O), 3.17 (d, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=6.0), 3.25 (d, 1H, H(1′), $J_{1',1'}$=9.6, $J_{1',2}$=3.9), 3.41 (t, 1H, H(7), $J_{7,8}$=$J_{7,6}$=5.3), 4.40 (s, 2H, OCH_2O); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.2, 35.8, 36.6, 38.1, 39.6, 40.0, 40.9, 42.2, 55.1, 70.1, 80.8, 96.4, 213.9; MS (EI, 70 eV, 30 °C): *m/z* (%)=180 (24), 167 (16), 149 (19), 139 (10), 121 (22), 107 (31), 93 (21), 79 (16), 55 (11), 45 (100); HRMS (EI, 70 eV, 80 °C) calcd for $C_{13}H_{22}O_4$ $(M)^+$: 242.1518, found: 242.1524; Anal. Calcd for $C_{13}H_{22}O_4$: C=64.15%, H=9.34%, found: C=64.18%, H=9.15%.

5.14. (±)-(1*R**,2*S**,4*R**,6*S**,7*R**,8*S**)-2-(2,4-Dioxapentyl)-4,7-dihydroxy-8-methylbicyclo[4.3.0]nonane (15)

To **14** (3.7 g, 15 mmol) dissolved in acetic acid (75 mL), $NaB(OAc)_3H$ (15.8 g, 75 mmol) was added. The reaction mixture was stirred at room temperature for 12 h, then cautiously neutralized with satd aq $NaHCO_3$ and extracted with dichloromethane (4×). The combined organic layers were washed with satd aq $NaHCO_3$ and brine and dried over $MgSO_4$. The product was purified on silica gel (petroleum ether/ethyl acetate 1:2) and isolated as a colourless oil (3.0 g, 81%). IR (cm^{-1}, film): 3387, 2928, 1456, 1374, 1211; ^1H NMR (400 MHz, C_6D_6) δ (ppm) 0.95 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 1.09 (dt, 1H, H(9β), $J_{9\beta,1}$∼$J_{9\beta,8}$∼7.5, $J_{9\beta,9\alpha}$=12.9), 1.23 (dt, 1H, H(3β), $J_{3\beta,3\alpha}$=12.4,

$J_{3\beta,2}$~$J_{3\beta,2}$~10), 1.61 (ddd, 1H, H(5β), $J_{5\beta,5\alpha}$=13.5, $J_{5\beta,4}$=8.7, $J_{5\beta,6}$=6.3), 1.67 (m, 1H, H(1), $J_{1,9\alpha}$=3.3, $J_{1,9\beta}$= 7.2), 1.75 (m, 1H, H(2)), 1.81 (ddd, 1H, H(9α), $J_{9\alpha,1}$=3.3, $J_{9\alpha,8}$=8.5, $J_{9\alpha,9\beta}$=12.7), 1.93 (m, 1H, H(8)), 1.98 (dd, 1H, H(5α), $J_{5\alpha,5\beta}$=13.5, $J_{5\alpha,6}$~$J_{5\alpha,4}$~4–5), 2.11 (m, 2H, H(6), H(3α)), 2.7 (br s, 2H, OH), 3.20 (s, 3H, CH_3O), 3.34 (dd, 1H, H(1′), $J_{1',1'}$=9.3, $J_{1',2}$=6.4), 3.51 (dd, 1H, H(1′), $J_{1',1'}$=9.4, $J_{1',2}$=4.1), 3.56 (t, 1H, H(7), $J_{7,8}$=6.1, $J_{7,6}$= 4.3), 4.18 (tt, 1H, H(4), $J_{4,5\beta}$~$J_{4,3\beta}$~9.2, $J_{4,5\alpha}$~$J_{4,3\alpha}$~4.3), 4.51 (d, 1H, OCH_2O, $J_{3',3'}$=6.4), 4.53 (d, 1H, OCH_2O, $J_{3',3'}$=6.4); ^{13}C NMR (100 MHz, C_6D_6) δ 20.6, 33.3, 36.7, 37.6, 39.1, 39.5, 41.7, 42.1, 55.2, 68.05, 72.4, 83.1, 97.0; MS (EI, 70 eV, 30 °C): *m/z* (%)=245 (100), 195 (7), 181 (10), 163 (24), 151 (23), 121 (11), 107 (22), 93 (25), 81 (25), 67 (12), 55 (16).

5.15. (±)-(1*R**,2*S**,4*R**,6*S**,7*R**,8*S**)-4-(*tert*-Butyldimethylsiloxy)-2-(2,4-dioxapentyl)-7-hydroxy-8-methylbicyclo[4.3.0]nonane (16)

To **15** (3 g, 12 mmol) dissolved in dry DMF (250 mL), *tert*-butyldimethylsilyl chloride (2 g, 13 mmol) and imidazole (1.8 g, 24 mmol) were added and the mixture was stirred at room temperature for 1 h. Water was added and the mixture was extracted with toluene (4×). The combined organic layers were washed with brine and dried over $MgSO_4$. The product was purified on silica gel (petroleum ether/ethyl ether 3:1) and isolated as a colourless oil (3.4 g, 80%). IR (cm^{-1}, film): 3480, 2929, 1472, 1253; ^{1}H NMR (400 MHz, C_6D_6) δ (ppm) 0.15 (s, 3H, $SiCH_3$), 0.17 (s, 3H, $SiCH_3$), 0.86 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 0.98 (br s, 1H, OH), 1.04 (s, 9H, $C(CH_3)_3$), 1.33 (dt, 1H, H(3β), $J_{3\beta,3\alpha}$=12.6, $J_{3\beta,2}$~$J_{3\beta,2}$~9.7), 1.63 (ddd, 1H, H(5β), $J_{5\beta,5\alpha}$= 13.6, $J_{5\beta,4}$=8.5, $J_{5\beta,6}$=6.9), 1.67–1.77 (m, 4H, H(2), H(8), H(9α), H(9β)), 1.8 (dt, 1H, H(1), $J_{1,2}$=12.1, $J_{1,9\beta}$=$J_{1,6}$=4), 1.82 (ddt, 1H, H(5α), $J_{5\alpha,5\beta}$~14, $J_{5\alpha,6}$=$J_{5\alpha,4}$=4.4, $J_{5\alpha,3\alpha}$=1), 2.05 (m, 1H, H(6), $J_{6,5\alpha}$~$J_{6,5\beta}$~$J_{6,1}$~$J_{6,7}$~4–7), 2.08 (ddt, 1H, H(3α), $J_{3\alpha,3\beta}$=12.5, $J_{3\alpha,2}$~$J_{3\alpha,4}$~3, $J_{3\alpha,5\alpha}$=1), 3.19 (s, 3H, CH_3O), 3.34 (dd, 1H, H(1′), $J_{1',1'}$=9.3, $J_{1',2}$=6.0), 3.35 (t, 1H, H(7), $J_{7,8}$=$J_{7,6}$=6.2), 3.55 (dd, 1H, H(1′), $J_{1',1'}$=9.3, $J_{1',2}$=4.4), 4.20 (tt, 1H, H(4), $J_{4,5\beta}$~$J_{4,3\beta}$~9.0, $J_{4,5\alpha}$~$J_{4,3\alpha}$~4.4), 4.51 (d, 1H, OCH_2O, $J_{3',3'}$=6.4), 4.53 (d, 1H, OCH_2O, $J_{3',3'}$=6.4); ^{13}C NMR (100 MHz, C_6D_6) δ −3.64, −3.60, 19.1, 20.75, 26.9, 34.2, 37.05, 38.3, 39.6, 39.8, 42.0, 42.55, 55.5, 69.85, 72.9, 83.7, 97.4; MS (EI, 70 eV, 30 °C): *m/z* (%)=325 (1), 269 (3), 239 (6), 195 (8), 177 (23), 147 (100), 119 (46), 105 (49), 91 (35), 75 (44), 45 (98).

5.16. (±)-(1*R**,2*S**,4*R**,6*S**,8*S**)-4-(*tert*-Butyldimethylsilyloxy)-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]nonan-7-one (17)

To (1.35 g, 6.2 mmol) pyridinium chlorochromate and crushed molecular sieves (0.3 nm) suspended in dry dichloromethane (60 mL), **16** (1.48 g, 4.13 mmol) dissolved in dichloromethane (20 mL) was added and stirred at room temperature for 3 h. The reaction mixture was then filtered through a plug of silica gel with ethyl acetate. The product was purified on silica gel (petroleum ether/diethyl ether 3:1) and isolated as a colourless oil (1.32 g, 90%). IR (cm^{-1}, film): 2929, 2857, 1738, 1253; ^{1}H NMR (400 MHz, C_6D_6) δ (ppm) −0.02 (s, 3H, $SiCH_3$), 0.00 (s, 3H, $SiCH_3$), 0.81 (s, 9H, $C(CH_3)_3$), 1.05 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.1), 1.09 (dt, 1H, H(3β), $J_{3\beta,3\alpha}$~$J_{3\beta,2}$~12–13, $J_{3\beta,4}$~11), 1.28 (m, 1H, H(2)), 1.35 (ddd, 1H, H(5β), $J_{5\beta,5\alpha}$= 12.8, $J_{5\beta,4}$=10.9, $J_{5\beta,6}$=6.5), 1.43 (ddd, 1H, H(9β), $J_{9\alpha,9\beta}$= 12.8, $J_{9\beta,8}$=11.0, $J_{9\beta,1}$=6.0), 1.81 (m, 1H, H(3α), $J_{3\alpha,3\beta}$=12.3, $J_{3\alpha,2}$~$J_{3\alpha,4}$~3–4, $J_{3\alpha,5\alpha}$=2.3), 2.00 (dt, 1H, H(1), $J_{1,2}$=11.6, $J_{1,9\beta}$~$J_{1,6}$~6.7), 2.13 (ddq, 1H, H(8), J_{8,CH_3}=7.1, $J_{8,9\beta}$~10.8, $J_{8,9\alpha}$~8), 2.23 (dd, 1H, H(9α), $J_{9\alpha,9\beta}$=12.8, $J_{9\alpha,8}$=8.4), 2.30 (ddt, 1H, H(5α), $J_{5\alpha,5\beta}$= 12.9, $J_{5\alpha,4}$=4.4, $J_{5\alpha,6}$~$J_{5\alpha,3\alpha}$~2), 2.37 (ddd, 1H, H(6), $J_{6,5\alpha}$=1.8, $J_{6,5\beta}$~$J_{6,1}$~7), 3.29 (tt, 1H, H(4), $J_{4,5\beta}$= $J_{4,3\beta}$~10.8, $J_{4,5\alpha}$=$J_{4,3\alpha}$=4.2), 3.29 (s, 3H, CH_3O), 3.38 (dd, 1H, H(1′), $J_{1',1'}$=9.6, $J_{1',2}$=6.2), 3.50 (dd, 1H, H(1′), $J_{1',1'}$=9.6, $J_{1',2}$=3.9), 4.54 (d, 1H, OCH_2O, $J_{3',3'}$=6.5), 4.56 (d, 1H, OCH_2O, $J_{3',3'}$=6.5); ^{13}C NMR (100 MHz, C_6D_6) δ −4.9, −4.3, 15.8, 18.0, 25.7, 32.6, 32.7, 35.7, 37.1, 38.2, 39.9, 49.8, 55.0, 67.9, 70.8, 96.5, 220.95; MS (EI, 70 eV, 30 °C): *m/z* (%)=299 (8), 269 (22), 253 (9), 237 (23), 223 (2), 193 (3), 175 (10), 163 (15), 119 (29), 105 (16), 89 (25), 59 (6), 45 (100).

5.17. (±)-(1*R**,2*S**,4*R**,6*S**,7*S**,8*S**)-4-(*tert*-Butyldimethylsilyloxy)-2-(2,4-dioxapentyl)-7-hydroxy-8-methylbicyclo[4.3.0]nonane (18)

A solution of Li (32 mg, 4.6 mmol) in liquid ammonia (20 mL) was added dropwise at −78 °C under argon to a solution of **17** (78 mg, 219 μmol) in dry methanol (5 mL). The mixture was stirred at −45 °C until the blue colour had disappeared (15–20 min). Ammonia was removed by cautious warming of the reaction. Satd aq NH_4Cl was added to the mixture, which was extracted with dichloromethane (4×). The combined organic layers were washed with brine, dried over $MgSO_4$ and evaporated under reduced pressure. The crude product was purified on silica gel (petroleum ether/diethyl ether 3:1) affording 30 mg (39%) of **18** and 40 mg (51%) of **16**. IR (cm^{-1}, film): 3437, 2929, 2858, 1472, 1380, 1255; ^{1}H NMR (400 MHz, C_6D_6) δ (ppm) 0.15 (s, 6H, $SiCH_3$), 0.75 (br s, 1H, OH), 0.86 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 1.03 (s, 9H, $C(CH_3)_3$), 1.20–1.35 (m, 3H, H(9α), H(2), H(5β)), 1.49–1.59 (m, 2H, H(6), H(3β)), 1.64 (ddd, 1H, H(9β), $J_{9\alpha,9\beta}$=13.1, $J_{9\beta,8}$=8.0, $J_{9\beta,1}$=2.0), 1.92 (m, 1H, H(1)), 1.92 (sept, 1H, H(8), J_{8,CH_3}~$J_{8,7}$~ $J_{8,9\alpha}$~$J_{8,9\beta}$~7–8), 2.02 (ddt, 1H, H(3α), $J_{3\alpha,3\beta}$=13.2, $J_{3\alpha,2}$=$J_{3\alpha,4}$=4, $J_{3\alpha,5\alpha}$=1.8), 2.12 (ddd, 1H, H(5α), $J_{5\alpha,5\beta}$~ 9.1, $J_{5\alpha,4}$=4.3, $J_{5\alpha,3\alpha}$=1.7), 3.17 (s, 3H, CH_3O), 3.22 (dd, 1H, H(1′), $J_{1',1'}$=9.4, $J_{1',2}$=6.1), 3.42 (dd, 1H, H(1′), $J_{1',1'}$=9.4, $J_{1',2}$=3.5), 3.65 (t, 1H, H(7), $J_{7,8}$=$J_{7,6}$=8.1), 3.83 (tt, 1H, H(4), $J_{4,5\beta}$~$J_{4,3\beta}$~9.5, $J_{4,5\alpha}$~$J_{4,3\alpha}$~4.6), 4.47 (d, 1H, OCH_2O, $J_{3',3'}$=6.4), 4.49 (d, 1H, OCH_2O, $J_{3',3'}$=6.4); ^{13}C NMR (100 MHz, C_6D_6) δ −3.60, 16.0, 19.05, 26.8, 35.4, 35.8, 37.4, 37.7, 39.3, 39.8, 47.0, 55.5, 68.8, 72.3, 77.1, 97.4; MS (EI, 70 eV, 30 °C): *m/z* (%)=313 (1), 271 (2), 239 (13), 165 (5), 147 (100), 119 (15), 105 (32), 91 (28), 75 (29), 45 (58).

5.18. (±)-(1*R**,2*S**,4*R**,6*S**,7*S**,8*S**)-7-(Benzyloxy)-4-(*tert*-butyldimethylsiloxy)-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]nonane (19)

Benzyl bromide (90 μL, 3 equiv), NaH (36 mg, suspension in oil, 3 equiv) and tetrabutylammonium iodide (47 mg, 0.5 equiv) were added to a solution of **18** (91 mg,

254 μmol) in dry THF (10 mL), which was heated for 12 h (bath temperature 80 °C). The reaction was quenched with satd aq NH_4Cl and extracted with diethyl ether (4×). The combined organic layers were washed with brine, dried over $MgSO_4$ and evaporated under reduced pressure. The crude compound was purified on silica gel (petroleum ether/diethyl ether 25:1) affording 80 mg (70%) of product. IR (cm^{-1}, film): 3034, 2929, 2896, 2857, 1472, 1459, 1255; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.03 (s, 3H, $SiCH_3$), 0.05 (s, 3H, $SiCH_3$), 0.90 (s, 9H, $C(CH_3)_3$), 0.99 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 1.11 (dt, 1H, H(3β), $J_{3\alpha,3\beta}$=$J_{3\beta,2}$=12.4, $J_{3\beta,4}$=10.3), 1.37 (m, 1H, H(2), $J_{2,3\beta}$=12.4, $J_{2,1}$=10.1, $J_{2,1'}$=7.1, $J_{2,1'}$~$J_{2,3\alpha}$~3.8), 1.47 (m, 2H, H(5β), H(9β)), 1.64 (ddt, 1H, H(1), $J_{1,2}$=10.1, $J_{1,9\beta}$=$J_{1,6}$=7.7, $J_{1,9\alpha}$=2.2), 1.77 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=13.4, $J_{9\alpha,8}$=8.1, $J_{9\alpha,1}$=2.1), 1.97 (m, 2H, H(3α), H(5α)), 2.29 (m, 1H, H(6)), 2.32 (sept, 1H, H(8), J_{8,CH_3}=7.1, $J_{8,7}$~$J_{8,9\alpha}$~$J_{8,9\beta}$~7), 3.27 (dd, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=7.1), 3.35 (s, 3H, CH_3O), 3.49 (dd, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=3.8), 3.66 (dd, 1H, H(7), $J_{7,8}$=7.7, $J_{7,6}$=9.4), 3.73 (tt, 1H, H(4), $J_{4,5\beta}$~$J_{4,3\beta}$~10.1, $J_{4,5\alpha}$~$J_{4,3\alpha}$~4.3), 4.42 (d, 1H, CH_2Ph, J=11.7), 4.58 (d, 1H, OCH_2O, $J_{3',3'}$=6.5), 4.60 (d, 1H, CH_2Ph, J=11.7), 4.61 (d, 1H, OCH_2O, $J_{3',3'}$=6.5), 7.35 (m, 5H(aryl)); ^{13}C NMR (100 MHz, $CDCl_3$) δ −4.6, −4.5, 15.8, 18.2, 25.9, 32.7, 34.6, 36.0, 36.4, 38.9, 39.3, 42.7, 55.1, 67.6, 71.5, 72.3, 83.1, 96.6, 127.5, 127.7, 127.8, 128.3, 128.4, 138.8; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=397 (1), 371 (5), 340 (2), 295 (2), 239 (28), 221 (5), 181 (7), 147 (88), 91 (100), 45 (84).

5.19. (±)-(1*R**,2*S**,4*R**,6*S**,7*S**,8*S**)-7-(Benzyloxy)-2-(2,4-dioxapentyl)-4-hydroxy-8-methylbicyclo[4.3.0]-nonane (20)

Tetrabutylammonium fluoride trihydrate (100 mg, 2 equiv) was added to a solution of **19** (69 mg, 154 μmol) in dry THF (3 mL), which was then stirred for 24 h at room temperature, quenched with satd aq NH_4Cl and extracted with ethyl acetate (4×). The combined organic layers were washed with brine, dried over $MgSO_4$ and evaporated under reduced pressure. The crude compound was purified on silica gel (petroleum ether/ethyl acetate 2:1) affording 47 mg (91%) of product. IR (cm^{-1}, film): 3401, 2927, 2352, 2334, 1454; ^1H NMR (400 MHz, C_6D_6) δ (ppm) 1.01 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.0), 1.06 (dt, 1H, H(3β), $J_{3\alpha,3\beta}$=$J_{3\beta,2}$=11.8, $J_{3\beta,4}$=10.1), 1.18 (m, 1H, H(2), $J_{2,3\beta}$=11.8, $J_{2,1}$=10.2, $J_{2,1'}$=6.5, $J_{2,1'}$~$J_{2,3\alpha}$~3.6), 1.35 (m, 2H, H(5β), H(9β)), 1.53 (ddt, 1H, H(1), $J_{1,2}$=10.2, $J_{1,9\beta}$=$J_{1,6}$=7.4, $J_{1,9\alpha}$=2.7), 1.60 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=13.1, $J_{9\alpha,8}$=8.2, $J_{9\alpha,1}$=2.5), 2.00 (m, 2H, H(3α), H(5α)), 2.07 (sept, 1H, H(8), J_{8,CH_3}~$J_{8,7}$~$J_{8,9\alpha}$~$J_{8,9\beta}$~7.3), 2.25 (m, 1H, H(6), $J_{6,7}$~8, $J_{6,1}$~7, $J_{6,5}$~$J_{6,5}$~4), 3.18 (s, 3H, CH_3O), 3.20 (dd, 1H, H(1′), $J_{1',1'}$=9.4, $J_{1',2}$=6.5), 3.36 (dd, 1H, H(1′), $J_{1',1'}$=9.4, $J_{1',2}$=3.6), 3.44 (t, 1H, H(7), $J_{7,8}$~$J_{7,6}$=8), 3.54 (tt, 1H, H(4), $J_{4,5\beta}$~$J_{4,3\beta}$~10, $J_{4,5\alpha}$~$J_{4,3\alpha}$~4–5), 4.27 (d, 1H, CH_2Ph, J=12.0), 4.43 (d, 1H, CH_2Ph, J=12.0), 4.46 (d, 1H, OCH_2O, $J_{3',3'}$=6.7), 4.49 (d, 1H, OCH_2O, $J_{3',3'}$=6.5), 7.25 (m, 5H(aryl)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.9, 32.4, 34.1, 35.9, 36.3, 38.4, 39.0, 42.5, 55.1, 66.8, 71.2, 72.1, 82.6, 96.5, 127.5, 127.7, 128.3, 138.8; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=302 (18), 289 (6), 270 (4), 254 (3), 226 (10), 211 (25), 181 (53), 163 (45), 135 (31), 91 (99), 81 (42), 65 (34), 55 (28), 45 (100).

5.20. (±)-(1*R**,2*S**,6*S**,7*S**,8*S**)-7-(Benzyloxy)-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]nonan-4-one (21)

Pyridinium chlorochromate (35.5 mg, 165 μmol) and crushed molecular sieves (0.3 nm) were added to a solution of **20** (36.7 mg, 110 μmol) in dry dichloromethane (3 mL). The solution was stirred at room temperature for 3 h and filtered through a plug of silica gel with ethyl acetate. The solvent was removed under reduced pressure and the crude product was purified on silica gel (petroleum ether/diethyl ether 1:1) giving 29 mg (80%) of **21**. ^1H NMR (400 MHz, C_6D_6) δ (ppm) 0.97 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 1.23 (dt, 1H, H(9β), $J_{9\beta,9\alpha}$=12.9, $J_{9\beta,1}$~$J_{9\beta,8}$=6–7), 1.33 (m, 1H, H(1)), 1.46 (m, 1H, H(2)), 1.59 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=12.8, $J_{9\alpha,8}$=8.7, $J_{9\alpha,1}$=6.8), 1.82 (dd, 1H, H(5α), $J_{5\alpha,5\beta}$=15.1, $J_{5\alpha,6}$=12.3), 1.88 (m, 1H, H(8)), 1.91 (dd, 1H, H(3β), $J_{3\alpha,3\beta}$=17.6, $J_{3\beta,2}$=12.3), 2.16 (m, 1H, H(6), $J_{6,7}$=4.8, $J_{6,1}$=10.3, $J_{6,5\beta}$=5.6, $J_{6,5\alpha}$~12.3), 2.33 (dd, 1H, H(5β), $J_{5\alpha,5\beta}$=15.0, $J_{5\beta,6}$=5.6), 2.42 (dd, 1H, H(3α), $J_{3\alpha,3\beta}$=17.7, $J_{3\alpha,2}$=3.7), 3.10 (dd, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=6.5), 3.12 (t, 1H, H(7), $J_{7,8}$~$J_{7,6}$=5), 3.13 (s, 3H, CH_3O), 3.23 (dd, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=3.9), 4.21 (d, 1H, CH_2Ph, J=12.2), 4.25 (d, 1H, CH_2Ph, J=12.2), 4.38 (d, 1H, OCH_2O, $J_{3',3'}$=6.5), 4.41 (d, 1H, OCH_2O, $J_{3',3'}$=6.5), 7.20 (m, 5H(aryl)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.7, 34.7, 35.8, 36.4, 39.2, 40.0, 42.2, 42.25, 55.2, 70.0, 71.4, 88.1, 96.5, 127.5, 127.6, 127.7, 128.4, 138.6, 212.6; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=287 (9), 270 (3), 237 (3), 194 (3), 181 (25), 164 (6), 149 (8), 136 (4), 121 (7), 107 (6), 91 (97), 81 (7), 65 (9), 55 (7), 45 (100).

5.21. (±)-(*E*)-(1*R**,2*S**,6*S**,7*S**,8*S**)-7-(Benzyloxy)-2-(2,4-dioxapentyl)-8-methyl-4-[(2,4,6-triisopropylphenylsulfonyl)hydrazono]bicyclo[4.3.0]nonane (22)

A solution of **21** (24.2 mg, 73 μmol) in dry diethyl ether (1.5 mL) was treated with trisylhydrazide (25 mg, 80 μmol) and stirred for 24 h at room temperature. The solvent was removed under reduced pressure. The crystalline hydrazones were separated on silica gel (petroleum ether/ethyl acetate 5:1) affording 39 mg (78%) of (*E*)-**22** and 4 mg (9%) of (*Z*)-**22**. ^1H NMR (400 MHz, C_6D_6) δ (ppm) 0.97 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.9), 1.23 (dt, 1H, H(9β), $J_{9\alpha,9\beta}$=12.9, $J_{9\alpha,1}$~$J_{9\alpha,8}$=6–7), 1.33 (m, 1H, H(1)), 1.46 (m, 1H, H(2)), 1.59 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=12.8, $J_{9\alpha,8}$=8.7, $J_{9\alpha,1}$=6.8), 1.82 (dd, 1H, H(5α), $J_{5\alpha,5\beta}$=15.1, $J_{5\alpha,6}$=12.3), 1.88 (m, 1H, H(8)), 1.91 (dd, 1H, H(3β), $J_{3\alpha,3\beta}$=17.6, $J_{3\beta,2}$=12.3), 2.16 (m, 1H, H(6), $J_{6,7}$=4.8, $J_{6,1}$=10.3, $J_{6,5\beta}$=5.6, $J_{6,5\alpha}$~12.3), 2.33 (dd, 1H, H(5β), $J_{5\beta,5\alpha}$=15.0, $J_{5\beta,6}$=5.6), 2.42 (dd, 1H, H(3α), $J_{3\alpha,3\beta}$=17.7, $J_{3\alpha,2}$=3.7), 3.10 (dd, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=6.5), 3.12 (t, 1H, H(7), $J_{7,8}$~$J_{7,6}$=5), 3.13 (s, 3H, CH_3O), 3.23 (dd, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=3.9), 4.21 (d, 1H, CH_2Ph, J=12.2), 4.25 (d, 1H, CH_2Ph, J=12.2), 4.38 (d, 1H, OCH_2O, $J_{3',3'}$=6.5), 4.41 (d, 1H, OCH_2O, $J_{3',3'}$=6.5), 7.20 (m, 5H(aryl)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 13.7, 34.7, 35.8, 36.4, 39.2, 40.0, 42.2, 42.25, 55.2, 70.0, 71.4, 88.1, 96.5, 127.5, 127.6, 127.7, 128.4, 138.6, 212.6; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=287 (9), 270 (3), 237 (3), 194 (3), 181 (25), 164 (6), 149 (8), 136 (4), 121 (7), 107 (6), 91 (97), 81 (7), 65 (9), 55 (7), 45 (100).

5.22. (±)-(1*R**,2*S**,6*S**,7*S**,8*S**)-7-(Benzyloxy)-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]non-3-ene (23)

s-BuLi (95 μL, 1.3 M in cyclohexane, 123 μmol) was added dropwise to a solution of (*E*)-**22** (34.2 mg, 56 μmol) in dry THF (2 mL) at −78 °C under argon. After 30 min at −78 °C, the reaction mixture was stirred at 0 °C for 15 min and then immediately recooled to −78 °C where it was quenched with satd aq NH_4Cl. The mixture was extracted with ethyl acetate (4×). The combined organic layers were washed with satd aq $NaHCO_3$ and brine, dried over $MgSO_4$ and evaporated under reduced pressure. The crude product was purified on silica gel (petroleum ether/diethyl ether 8:1) affording 15 mg (85%) of product. IR (cm^{-1}, film): 3027, 2927, 1454; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 1.01 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.0), 1.55 (ddd, 1H, H(9β), $J_{9\beta,9\alpha}$=13.0, $J_{9\beta,8}$=7.5, $J_{9\beta,1}$=5.7), 1.70 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=13.0, $J_{9\alpha,8}$=8.4, $J_{9\alpha,1}$=5.0), 1.82 (m, 1H, H(5)), 1.99 (m, 1H, H(2)), 2.02 (m, 1H, H(1)), 2.19 (m, 1H, H(6)), 2.20 (m, 1H, H(5)), 2.34 (sept, 1H, H(8), $J_{8,CH_3}\sim J_{8,7}\sim J_{8,9}\sim J_{8,9}\sim$7), 3.37 (s, 3H, CH_3O), 3.40 (dd, 1H, H(1′), $J_{1',1'}$=9.4, $J_{1',2}$=6.6), 3.49 (dd, 1H, H(1′), $J_{1',1'}$=9.4, $J_{1',2}$=5.3), 3.56 (t, 1H, H(7), $J_{7,8}=J_{7,6}$=6.5), 4.46 (d, 1H, CH_2Ph, J=11.9), 4.55 (d, 1H, CH_2Ph, J=11.9), 4.61 (m, 2H, OCH_2O), 5.70 (m, 1H, H(3), $J_{3,4}$=10), 5.78 (m, 1H, H(4), $J_{4,3}$=10, $J=J$=3.9, J=2), 7.35 (m, 5H(aryl)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.4, 25.5, 33.2, 35.1, 38.1, 38.8, 39.9, 55.2, 71.0, 71.3, 86.4, 96.6, 127.3, 127.4, 127.5, 128.3, 128.3, 139.1; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=316 (6), 254 (25), 225 (3), 193 (4), 164 (11), 145 (14), 105 (20), 91 (100), 79 (12), 57 (7). NOESY crosspeaks supporting the Δ^3 position of the double bond: 4/5, 3/2, 3/CH_2O, CH_2O/2, 7/2, 7/8, 7/5.

5.23. (1*R*,2*S*,6*S*,7*R*,8*S*)-7-(*tert*-Butyldimethylsiloxy)-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]nonan-4-one (24)

To a solution of (+)-**14** (4.96 g, 20.5 mmol) in dry DMF (100 mL) were added imidazole (1.81 g, 26.6 mmol) and TBSCl (3.39 g, 22.5 mmol). The reaction mixture was stirred overnight at room temperature and then quenched with satd aq $NaHCO_3$ (50 mL). The aqueous layer was extracted with diethyl ether (5×100 mL), and the combined organic layers were washed with brine (100 mL) and dried over $MgSO_4$. The crude product was purified on silica gel (petroleum ether/ethyl acetate 2:1) to give a colourless oil (7.14 g, 98%). $[\alpha]_D^{20}$ +115.9 (*c* 1.0, $CHCl_3$). IR (cm^{-1}, film): 2954, 2929, 2885, 2858, 2769.5, 2360, 2343, 1716; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.00 (s, 3H, $SiCH_3$); 0.02 (s, 3H, $SiCH_3$), 0.85 (s, 9H, $SiC(CH_3)_3$), 0.91 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=6.8), 1.47 (ddd, 1H, H(9β), $J_{9\beta,9\alpha}$=13.1, $J_{9\beta,1}$=7.7, $J_{9\beta,8}$=5.7), 1.81 (ddd, 1H, H(9α), $J_{9\alpha,9\beta}$=12.6, $J_{9\alpha,,8}$=7.3, $J_{9\alpha,1}$=4.9), 1.97–2.11 (m, 4H, H(1), H(2), H(3α), H(8)), 2.23 (A-part of ABM-system, 1H, H(5β), $J_{5\beta,5\alpha}$=14.1, $J_{5\beta,6}$=5.1), 2.42 (M-part of ABM-system, 1H, H(6), $J_{6,5\alpha}$=10.1, $J_{6,7}\sim$4.7, $J_{6,5\beta}\sim$5.1, $J_{6,1}$=8.6), 2.48 (B-part of ABM-system, 1H, H(5α), $J_{5\alpha,5\beta}$=14.1, $J_{5,6}$=10.1), 2.50 (1H, H(3α), $J_{3\alpha,3\beta}$=14.4), 3.32 (s, 3H, OCH_3), 3.37 (A-part of ABX-system, 1H, H(1′), J_{gem}=9.4, $J_{1',2}$=5.3), 3.50 (B-part of ABX-system, 1H, H(1′), J_{gem}=9.4, $J_{1',2}$=2.7), 3.69 (dd, 1H, H(7), $J_{6,7}\sim J_{7,8}\sim$4.7), 4.56 (A-part of AB-system, 1H, OCH_2O, J_{gem}=8), 4.58 (B-part of AB-system, 1H, OCH_2O, J_{gem}=8.6); ^{13}C NMR (100 MHz, $CDCl_3$) δ −4.5, −4.4, 18.4 (2C), 26.2, 36.0, 36.8, 38.9, 40.0, 40.7, 40.8, 42.6, 55.6, 70.6, 81.7, 96.9, 214.1; MS (EI, 70 eV, 30 °C): *m*/*z* (%)=300 (12), 299 (53), 267 (10), 237 (14), 175 (16), 147 (11.5), 145 (20), 133 (8), 105 (12), 93 (9), 87 (16), 85 (84.5), 83 (100), 75 (26), 73 (17); HRMS (EI, 70 eV, 30 °C) calcd for $C_{15}H_{27}O_4Si$ (M−*t*-Bu)$^+$: 299.1679, found: 299.1660; Anal. Calcd for $C_{19}H_{36}O_4Si$: C=64.00%, H=10.18%, found: C=64.19%, H=10.10%.

5.24. (1*R*,2*S*,6*S*,7*R*,8*S*)-7-(*tert*-Butyldimethylsiloxy)-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]non-3-ene (25) and (1*R*,2*S*,6*S*,7*R*,8*S*)-7-(*tert*-Butyldimethylsiloxy)-2-(2,4-dioxapentyl)-8-methylbicyclo [4.3.0] non-4-ene (26)

Compound (+)-**24** (2.24 g, 6.28 mmol) and freshly prepared trisylhydrazide (1.91 g, 6.4 mmol) were dissolved in dry diethyl ether (50 mL) at 0 °C. The solution was stirred at 0 °C for 1 h, then at room temperature in the dark overnight. The solvent was removed by rotary evaporation at room temperature and the resulting foam was dried under vacuum for 1 h. The residue was then dissolved in dry THF (50 mL) and cooled to −78 °C. *s*-BuLi (14.5 mL, 1.3 M solution in cyclohexane, 18.8 mmol) was slowly added, producing a bright orange colour. The solution was stirred at −78 °C for 90 min, then at room temperature for 25 min, before being quenched with satd aq NH_4Cl (0.5 mL). THF was removed by rotary evaporation and satd aq $NaHCO_3$ (20 mL) was added to the residue. The mixture was extracted with dichloromethane (2×50 mL). The combined organic layers were washed with brine (20 mL) and dried over Na_2SO_4. The crude product was purified on silica gel (petroleum ether/diethyl ether 20:1) affording a colourless oil as a 10.5:1 mixture of regioisomers **25** and **26** (1.54 g, 72%). $[\alpha]_D^{20}$ +51.3 (*c* 1.0, $CHCl_3$). IR (cm^{-1}, film): 2955, 2928, 1463, 1376, 1250, 1213, 1152, 1110, 1044; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) −0.01 (s, 3H, $SiCH_3$), 0.01 (s, 3H, $SiCH_3$), 0.84 (s, 9H, $Si(C(CH_3)_3)$, 0.97 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.1), 1.22–1.27 (m, 1H, H(9)), 1.73 (ddd, 1H, H(9), J_{gem}=8.6, J=10.4, 12.8), 1.90–2.04 (m, 5H, H(1), H(5), H(6), H(8)), 2.05–2.11 (m, 1H, H(2), $w_{1/2}$=5.7), 3.32 (s, 3H, OCH_3), 3.34 (dd, B-part of ABX-system, 1H, CH_2O, J_{gem}=9.3, $J_{2,1'}$=7.1), 3.41 (dd, A-part of ABX-system, 1H, CH_2O, J_{gem}=9.3, $J_{2,1'}$=5.8), 3.64 (t, 1H, H(7), $J_{7,6}\sim J_{7,8}\sim$5.5), 4.59 (s, 2H, OCH_2O), 5.54–5.59 (m, 1H, H(3), $J_{3,4}$=10, $J_{3,2}$=3.8, $J_{3,5}=J_{lr}$=2), 5.76–5.82 (m, 1H, H(4), $J_{3,4}$=10, $J_{4,5}\sim J\sim$4, J=2); ^{13}C NMR (100 MHz, $CDCl_3$) δ −4.3, 20.3, 22.4, 26.2, 35.5, 36.4, 38.7, 39.0, 39.4, 55.5, 72.1, 84.2, 96.9, 126.7, 128.5; MS (EI, 70 eV, 40 °C): *m*/*z* (%)=341 (9), 299 (14), 283 (16), 251 (14), 223 (24), 222 (19), 221 (100), 159 (25), 147 (57), 145 (43), 133 (21), 105 (36), 91 (48), 89 (26), 75 (81), 73 (48); HRMS (EI, 70 eV, 40 °C) calcd for $C_{15}H_{27}O_3Si$ (M−*t*-Bu)$^+$: 283.1729, found: 283.1717.

5.25. (1*R*,2*S*,6*S*,7*R*,8*S*)-2-(2,4-Dioxapentyl)-8-methylbicyclo[4.3.0]non-3-en-7-ol (27) and (1*R*,2*S*,6*S*,7*R*,8*S*)-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]non-4-en-7-ol (27a)

(a) (+)-**25** (4.7 g, 13.8 mmol) was dissolved in dry THF (60 mL) and TBAF (27.7 mL, 1 M solution in THF,

27.7 mmol) was added at 0 °C. The solution was stirred overnight at room temperature. Water (60 mL) was added and the layers were separated. The aqueous layer was extracted with diethyl ether (3×50 mL) and the combined organic layers were washed with brine (100 mL) and dried over $MgSO_4$. The product was purified on silica gel (petroleum ether/diethyl ether 1:1) and isolated as a colourless oil (3.0 g, 96%). The Δ^4-regioisomer could be separated by repeated flash chromatography. *(b)* To a solution of **30** (2.2 g, 6.2 mmol) in acetic acid (30 mL), Zn (1.2 g, 18.5 mmol) was added. The reaction mixture was stirred at room temperature for 30 min. Satd aq $NaHCO_3$ (200 mL) was added and the mixture was extracted with diethyl ether (3×50 mL). The organic phases were combined, dried over Na_2SO_4 and evaporated under reduced pressure. The crude product was purified on silica gel (petroleum ether/diethyl ether 1:1) giving product **27** (1.2 g, 85%) as a colourless oil. $[\alpha]_D^{20}$ +165.0 (*c* 0.9, acetone). IR (cm^{-1}, film): 3422, 2931, 1151, 1109, 1076, 1042; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 1.08 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.1), 1.31 (ddd, 1H, H(9), $J_{9,9}$=13.0, J=5.6, J=7.6), 1.53 (d, 1H, $J_{OH,7}$=5.3, OH), 1.86 (ddd, 1H, H(9), $J_{9,9}$=13.0, J=8.1, J=10.0), 1.93–2.09 (m, 3H, H(1), H(5), H(8)), 2.09–2.22 (m, 3H, H(2), H(5), H(6)), 3.36 (s, 3H, OCH_3), 3.43 (AB-part of ABX-system, 2H, H(1′), $J_{1',1'}$=9.7, $J_{1',2}$=6.1, $J_{1',2}$=6.9), 3.76 (q, 1H, H(7), $J_{7,OH}\sim J_{7,6}\sim J_{7,8}\sim$5.3), 4.62 (s, 2H, H(3′)), 5.67 (m, 1H, H(3), $J_{3,4}$=10.0), 5.87 (m, 1H, H(4), $J_{4,3}$=10.0); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.0, 21.7, 35.5, 36.8, 38.4, 38.5, 38.9, 55.2, 71.5, 83.8, 96.5, 127.3, 127.5; HRMS (EI, 70 eV, 50 °C) calcd for $C_{12}H_{18}O_2$ $(M-CH_3OH)^+$: 194.1307, found: 194.1301. Data of Δ^4-regioisomer **27a**: $[\alpha]_D^{20}$ +156.8 (*c* 0.8, acetone). IR (cm^{-1}, film): 3456, 2929, 1456, 1212, 1150, 1111, 1081, 1045; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.94 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.1), 1.49 (ddd, 1H, H(9), $J_{9,9}$=13.4, $J_{9,1}$=9.0, $J_{9,8}$=4.7), 1.60 (br s, 1H, OH), 1.72 (m, 1H, H(2), $J_{2,1}$=8.7, $J_{2,3}$=8.5, $J_{2,1'}$=7.3, $J_{2,3}$=4.9, $J_{2,1'}$=4.7), 1.70 (ddd, 1H, H(9), $J_{9,9}$=13.4, $J_{9,8}$=7.4, $J_{9,1}$=5.4) 1.85 (m, 1H, H(3)), 1.99 (m, 1H, H(8), J_{8,CH_3}=7.1, $J_{8,9}$=7.2, $J_{8,9}$=4.5, $J_{8,7}$=4.2), 2.07 (m, 1H, H(1), $J_{1,9}$=5.4, $J_{1,9}\sim J_{1,6}\sim J_{1,2}\sim$8.9, 1H), 2.21 (dtt, 1H, H(3), $J_{3,3}$=17.5, $J_{3,2}=J_{3,4}$=4.9, $J_{3,5}=J_{lr}$=1.7), 2.62 (m, 1H, H(6) $w_{1/2}$=16.5), 3.33 (s, 3H, OCH_3), 3.36 (A-part of ABX-system, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=7.3), 3.50 (B-part of ABX-system, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',2}$=4.6), 3.73 (br t, 1H, H(7), $J_{7,6}=J_{7,8}$=4.2), 4.59 (AB-system, 2H, H(3′), $J_{3',3'}$=6.6), 5.69 (m, 1H, H(5), $J_{4,5}$=10.1), 5.97 (m, 1H, H(4), $J_{4,5}$=10.1); ^{13}C NMR (100 MHz, $CDCl_3$) δ 18.95, 26.85, 35.1, 35.95, 38.1, 39.6, 42.5, 55.1, 70.9, 80.9, 96.54, 124.3, 130.8; HRMS (EI, 70 eV, 50 °C) calcd for $C_{13}H_{22}O_3$ $(M)^+$: 226.1569, found: 226.1566.

5.26. (1*R*,2*S*,6*S*,7*R*,8*S*)-2-(2,4-Dioxapentyl)-8-methylbicyclo[4.3.0]non-3-en-7-one (28)

To a suspension of Dess–Martin periodinane (1.9 g, 4.4 mmol) in dry dichloromethane (15 mL) was added a solution of (+)-**27** (0.90 g, 4.0 mmol) in dry dichloromethane (15 mL) at room temperature. Diethyl ether (50 mL) and satd aq $NaHCO_3$ (50 mL) containing $Na_2S_2O_3\cdot 5H_2O$ (7.7 g) were added after 1 h. The mixture was stirred for 10 min and the organic phase was separated. The aqueous phase was extracted with diethyl ether (50 mL). The combined organic layers were dried over $MgSO_4$ and after removal of the solvent under reduced pressure the crude product was purified on silica gel (petroleum ether/diethyl ether 2:1) affording 0.84 g (94%) of a colourless oil. $[\alpha]_D^{20}$ +197.6 (*c* 1.0, acetone). IR (cm^{-1}, film): 2929, 1739, 1458, 1150, 1112, 1041; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 1.13 (d, 3H, CH_3(8), $J_{CH_3,8}$=6.8), 1.60 (ddd, 1H H(9), $J_{9,9}$=11.1, $J_{9,1}$=7.8, $J_{9,8}$=5.6), 1.98 (m, 1H, H(2), $J_{2,1}\sim$8, $J_{2,1'}$=5.9, $J_{2,1'}$=5.3, $J_{2,4}\sim$3, $J_{2,3}\sim$2), 2.15–2.28 (m, 4H, H(8,9,5,6)), 2.38 (td, 1H, H(1), $J_{1,2}\sim J\sim$7.8, $J\sim$2), 2.45 (m, 1H, H(5), $J_{5,5}$=18.44, $J_{5,6}\sim J_{5,4}\sim J_{5,3}\sim J_{lr}\sim$2), 3.35 (s, 3H, OCH_3), 3.45 (dd, 1H, H(1′), $J_{1',1'}$=9.3, $J_{1',2}$=5.9), 3.53 (dd, 1H, H(1′), $J_{1',1'}$=9.3, $J_{1',2}$=5.3), 4.64 (AB-system, J_{AB}=7.0, 2H, OCH_2O), 5.62 (dq, 1H, H(3), $J_{3,4}$=10.2, $J_{3,2}=J_{3,5}=J_{lr}$=2.1), 5.73 (ddt, 1H, H(4), $J_{4,3}$=10.2, $J_{4,5}$=3.8, $J_{4,5}\sim J_{4,2}\sim$3.0); ^{13}C NMR (100 MHz, $CDCl_3$) δ 16.0, 21.7, 33.3, 34.8, 36.2, 39.7, 46.3, 55.2, 70.9, 96.6, 126.2, 127.3, 221.3; MS (EI, 70 eV, 60 °C): 224 (11, M^+), 164 (23), 162 (85), 148 (25), 131 (27), 110 (30), 105 (55), 104 (49), 91 (100), 79 (56), 78 (40), 77 (52); HRMS (EI, 70 eV, 50 °C) calcd for $C_{13}H_{20}O_3$ $(M)^+$: 224.1412, found: 224.1401; Anal. Calcd for $C_{13}H_{20}O_3$: C=69.61%, H=8.99%, found: C=69.27%, H=8.91%.

5.27. SmI_2-reduction of ketone 28

Compound (+)-**28** (338 mg, 1.51 mmol) was dissolved in a mixture of water (0.3 mL) and THF (1.5 mL). The flask was flushed with argon and a solution of SmI_2 in THF (0.1 M, 60 mL) was added. After 2 h, the reaction was quenched with aq HCl (0.1 M, 50 mL) and the aqueous layer was extracted with diethyl ether (3×50 mL). The combined organic layers were washed with satd aq $Na_2S_2O_3$ (50 mL) and brine (50 mL), and then dried with Na_2SO_4. The solvent was removed under reduced pressure and the residue was chromatographed on silica gel (petroleum ether/diethyl ether 1:1) yielding 285 mg (84%) of a colourless oil as a 1:1.5 mixture of **29** and **27**.

5.28. (1*R*,2*R*,3*S*,4*S*,6*S*,7*R*,8*S*)-3-(2,4-Dioxapentyl)-2-iodo-6-methyl-10-oxatricyclo[5.2.1.0^{4,8}]decane (30) and (1*R*,2*S*,6*S*,7*S*,8*S*)-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]non-3-en-7-ol (29)

To a solution of the alcohols **29** and **27** (1:1.5) (1.25 g, 5.52 mmol) in dry dichloromethane (15 mL) were added K_2CO_3 (1.19 g, 8.6 mmol) and I_2 (1.09 g, 4.3 mmol) under argon at 0 °C. After 15 min at 0 °C, stirring was continued at room temperature for 3 h. The reaction was quenched with satd aq $Na_2S_2O_3$. The organic layer was separated and the aqueous phase was extracted with dichloromethane (2×10 mL). The combined organic layers were dried over Na_2SO_4. The solvent was removed under reduced pressure and the residue was chromatographed on silica gel (petroleum ether/diethyl ether 2:1, 1:1) affording 0.95 g (49%) of **30** as a colourless oil and 0.40 g (32%) of **29** as white crystals. Data for **30**: $[\alpha]_D^{20}$ +54.6 (*c* 0.8, acetone). IR (cm^{-1}, film): 2940, 1457; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 1.02 (d, 3H, CH_3(6), $J_{CH_3,6}$=7.3), 1.28 (ddd, 1H, H(5), $J_{5,5}\sim$12.4, $J_{5,6}$=8.3, $J_{5,4}\sim$5), 1.68 (m, 1H, H(3), $J_{3,2}\sim$8.2, $J_{3,1'}\sim$8.6, $J_{3,4}\sim$6.8, $J_{3,1'}\sim$5.7), 1.77 (dt, 1H, H(4), $J_{4,3}\sim$6.8, $J_{4,5}\sim J_{4,8}\sim$5.5), 1.99 (ddd, 1H, H(9), $J_{9,9}\sim$12.4, $J_{9,8}\sim$1.5, $J_{9,1}\sim$4–5), 2.00 (dd, 1H, H(5), $J_{5,5}\sim$12.4, $J_{5,6}\sim$7.3),

2.46 (m, 1H, H(8)), 2.48 (sextett, 1H, H(6), $J_{6,CH_3}\sim J_{6,5}\sim J_{6,5}\sim$7.5), 2.72 (d, 1H, H(9), $J_{9,9}$=12.4), 3.40 (s, 3H, OCH_3), 3.47 (dd, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',3}$=8.6), 3.47 (dd, 1H, H(1′), $J_{1',1'}$=9.5, $J_{1',3}$=5.7), 3.95 (br d, 1H, H(7), $J_{7,8}$=4.0), 4.49 (dd, 1H, H(1), $J_{1,9}$=4.2, $J_{1,2}$=6.6), 4.60 (dd, 1H, H(2), $J_{2,1}$=6.6, $J_{2,3}$=8.2), 4.64 (d, 1H, H(3′), $J_{3',3'}$=6.6), 4.69 (d, 1H, H(3′), $J_{3',3'}$=6.6); ^{13}C NMR (100 MHz, $CDCl_3$) δ 19.8, 31.7, 38.0, 39.1, 39.6, 40.3, 44.1, 44.7, 55.65, 75.45, 79.6, 93.7, 96.75; MS (EI, 70 eV, 40 °C): *m/z* (%) 321 (4), 225 (100), 193 (72), 179 (44), 163 (79), 145 (45), 133 (46), 91 (76), 77 (51); MS (EI, 70 eV, 40 °C): 321 (>1, M^+-CH_3OH), 225 (91, M^+-I), 193 (40.5), 179 (28), 163 (54), 145 (35), 93 (63), 91 (100), 79 (97), 77 (68); HRMS (EI, 70 eV, 60 °C) calcd for $C_{13}H_{21}IO_3$ $(M-CH_3OH)^+$: 352.0535, found: 352.0541; Anal. Calcd for $C_{13}H_{21}IO_3$: C=44.33%, H=6.01%, found: C=44.30%, H=5.94%. Data for **29**: mp=35–37.5 °C; $[\alpha]_D^{20}$ +122.1 (*c* 0.3, acetone). IR (cm^{-1}, film): 3437, 2930, 1456, 1212, 1151, 1111, 1042; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.99 (d, 3H, C(8)CH_3, $J_{CH_3,8}$=7.1), 1.37 (br s, 1H, OH), 1.52 (dt, 1H, H(9), $J_{9,9}$=13.1, $J_{9,8}\sim J_{9,1}\sim$7.2), 1.75 (ddd, 1H, H(9), $J_{9,9}$=13.1, $J_{9,1}$=4.5, $J_{9,8}$=8.5), 1.85 (m, 1H, H(5), $J_{5,5}$=17.4, $J_{5,6}$=5.8, $J_{5,4}$=3.5, $J_{5,3}\sim J_{5lr}\sim$2.3), 2.06 (m, 3H, H(1), H(2), H(5)), 2.26 (m, 1H, H(6)), 2.28 (m, 1H, H(8), $J_{8,CH_3}\sim J_{8,7}\sim J_{8,9}\sim$7.0, $J_{8,9}$=8.6), 3.36 (s, 3H, OCH_3), 3.42 (dd, 1H, H(1′), $J_{1',1'}$=9.3, $J_{1',2}$=6.3), 3.50 (dd, 1H, H(1′), $J_{1',1'}$=9.3, $J_{1',2}$=5.7), 3.86 (dd, 1H, H(7), $J_{7,8}$=6.9, $J_{7,6}\sim$5.5), 4.63 (s, 2H, H(3′)), 5.70 (ddt, 1H, H(3), $J_{3,4}$=10, $J_{3,2}$=2.9, $J_{3,5}\sim J_{lr}\sim$2), 5.80 (dtd, 1H, H(4), $J_{4,3}$=10, $J_{4,5}\sim J_{4,5}\sim$3.9, $J_{4,2}$=2); ^{13}C NMR (100 MHz, $CDCl_3$) δ 14.9, 25.1, 34.4, 35.25, 37.9, 38.3, 43.2, 55.15, 71.1, 79.1, 96.55, 127.0, 127.9; MS (EI, 70 eV, 50 °C): 226 (<1, M^+), 164 (61), 146 (23), 134 (24), 133 (25), 105 (25), 93 (50), 92 (56), 91 (100), 79 (94.5), 78 (43), 77 (66); HRMS (EI, 70 eV, 50 °C) calcd for $C_{12}H_{18}O_2$ $(M-CH_3OH)^+$: 194.1307, found: 194.1312; Anal. Calcd for $C_{13}H_{22}O_3$: C=68.99%, H=9.80%, found: C=68.54%, H=9.54%.

5.29. (1*R*,2*S*,6*S*,7*S*,8*S*)-7-Acetoxy-2-(2,4-dioxapentyl)-8-methylbicyclo[4.3.0]non-3-ene (31)

To a stirred solution of alcohol **29** (370 mg, 1.63 mmol) in dry dichloromethane (16 mL) was added at 0 °C under argon dry pyridine (0.20 mL, 2.45 mmol), acetic anhydride (0.23 mL, 2.45 mmol) and 4-(dimethylamino)pyridine (19 mg, 0.16 mmol). The reaction mixture was stirred for 3 h at 0 °C and for a further 30 min at room temperature after which it was quenched with water (5 mL). The mixture was stirred for 30 min and then extracted with dichloromethane (2×). The combined organic layers were dried (Na_2SO_4) and evaporated under reduced pressure. The product was purified by flash chromatography on silica gel (petroleum ether/diethyl ether 5:1) and isolated as a colourless oil (374 mg, 85%), which solidified in the refrigerator to give white crystals. Mp=27–28 °C. $[\alpha]_D^{20}$ +108.4 (*c* 1.015, acetone). IR (cm^{-1}, film): 2934, 1735; ^{1}H NMR (400 MHz) δ 0.88 (d, 3H, CH_3(8), $J_{CH_3,8}$=7.1), 1.52 (dt, 1H, H(9), $J_{9,9}$=13.1, $J_{9,8}\sim J_{9,1}\sim$7.1), 1.78 (m, 1H, H(5)), 1.82 (ddd, 1H, H(9), $J_{9,9}$=13.1, $J_{9,8}$=8.8, $J_{9,1}$=4.8), 2.06 (s, 3H, CH_3CO), 2.05–2.13 (m, 2H, H(1,2)), 2.19 (dt, 1H, H(6), $J_{6,5}\sim J_{6,5}\sim$6.8, $J_{6,7}$=5.9), 2.24 (m, 1H, H(5), $J_{5,5}$=17.2, $J_{5,6}$=6.8, $J_{5,4}$=4.0, $J_{5,3}\sim J_{5,2}\sim$1.8), 2.46 (dsextet, 1H, H(8), $J_{8,CH_3}\sim J_{8,7}\sim J_{8,9}\sim$7.1, $J_{8,9}$=8.4), 3.37 (s, 3H, OCH_3), 3.44 (dd, 1H, H(1′), $J_{1',1'}$=9.35, $J_{1',2}$=5.8), 3.50 (dd, 1H, H(1′), $J_{1'.1'}$=9.3, $J_{1',2}$=5.3), 4.63 (s, 2H, OCH_2O), 4.885 (dd, 1H, H(7), $J_{7,8}$=7.1, $J_{7,6}$=5.7), 5.69 (ddt, 1H, H(3), $J_{3,4}$=10.1, $J_{3,2}$=2.9, $J_{3,5}\sim J_{lr}\sim$2), 5.77 (dtd, 1H, H(4), $J_{4,3}$=10.1, $J_{4,5}\sim J_{4,5}\sim$4.0, $J_{4,2}$=2); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.7, 21.4, 25.1, 33.5, 35.8, 38.3, 38.5, 41.0, 55.5, 71.4, 81.6, 96.9, 127.0, 128.1, 171.4; MS (EI, 70 eV, 50 °C): 208 (7, M^+-HOAc), 146 (53), 105 (28), 93 (21), 92 (35), 91 (100), 79 (55), 78 (25), 77 (35); HRMS (EI, 70 eV, 50 °C) calcd for $C_{13}H_{20}O_2$ $(M-HOAc)^+$: 208.1463, found: 208.1470; Anal. Calcd for $C_{15}H_{24}O_4$: C=67.14%, H=9.01%, found: C=66.92%, H=8.84%.

5.30. (1*R*,2*S*,6*S*,7*S*,8*S*)-7-Acetoxy-2-(hydroxymethyl)-8-methylbicyclo[4.3.0]non-3-ene (32)

To a stirred solution of **31** (51 mg, 0.19 mmol) in dry dichloromethane (1 mL) was added under argon at −78 °C NEt_3 (1 M in dry dichloromethane, 114 μL, 0.114 mmol). Me_2BBr[32] (1 M in dry dichloromethane, 570 μL, 0.57 mmol) was added slowly to the reaction. After 2 h at −78 °C, a mixture of THF (2 mL) and satd aq $NaHCO_3$ (1 mL) was added. The cooling bath was removed and diethyl ether was given to the mixture. The organic layer was separated and the aqueous layer was extracted with diethyl ether. The combined organic phases were washed with brine and dried (Na_2SO_4) The solvent was removed under reduced pressure. The residue was chromatographed on silica gel (petroleum ether/diethyl ether 1:1) giving the product (38 mg, 89%) as a colourless oil and the remaining starting material (5 mg, 10%). $[\alpha]_D^{20}$ +109.4 (*c* 0.38, acetone). IR (cm^{-1}, film): 3401br, 3021, 2934, 2874, 1735; ^{1}H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.87 (d, 3H, CH_3(8), $J_{CH_3,8}$=7.3), 1.49 (dt, 1H, H(9), $J_{9,9}$=13.0, $J_{9,8}\sim J_{9,1}\sim$7.3), 1.68 (br, 1H, OH), 1.78 (H(9), $J_{9,9}$=13.0, $J_{9,8}$=8.8, $J_{9,1}$=5.3), 1.79 (m, 1H, H(5)), 1.99 (m, (1H), H(2)), 2.10 (s, 3H, CH_3CO), 2.07 (m, 1H, H(1)), 2.17 (m, 1H, H(6)), 2.20 (m, 1H, H(5)), 2.44 (m, 1H, H(8), $J_{8,9}$=8.8, $J_{8,CH_3}=J_{8,9}=J_{8,7}$=7.2–7.3), 3.55 (dd, 1H, H(1′), $J_{1',1'}$=10.5, $J_{1',2}$=5.5), 3.61 (dd, 1H, H(1′), $J_{1',1'}$=10.5, $J_{1',2}$=5.2), 4.87 (dd, 1H, H(7), $J_{7,8}$=7.2, $J_{7,6}$=5.6), 5.64 (ddt, 1H, H(3), $J_{3,4}$=10, $J_{3,2}$=2.9, $J_{3,5}\sim J_{lr}\sim$2), 5.81 (dtd, 1H, H(4), $J_{4,3}$=10, $J_{4,5}\sim J_{4,5}\sim$3.9, $J_{4,2}$=2); ^{13}C NMR (100 MHz, $CDCl_3$) δ 15.3, 21.0, 24.5, 32.9, 34.9, 38.3, 40.1, 40.5, 65.9, 81.1, 126.9, 127.6, 171.1; MS (EI, 70 eV, 60 °C): 224 (<1, M^+), 164 (18, M^+-HOAc), 146 (13, $M^+-HOAc-H_2O$), 134 (15), 133 (100), 132 (21.5), 131 (33), 108 (13), 105 (17), 93 (16), 92 (21), 91 (71), 79 (38); HRMS (EI, 70 eV, 60 °C) calcd for $C_{13}H_{20}O_3$ (M^+): 224.1412, found: 224.1417.

NOESY crosspeaks: 2/8, 2/7, 1′/6 (confirm the stereochemistry at C-2), 2/3, 2′/3 (establish the Δ^3-position of the double bond), 2/7, CH_3(8)/6.

5.31. (1*R*,2*S*,6*R*,7*S*,8*S*)-2-(2,4-Dioxapentyl)-8-methyl-7-(triethylsiloxy)bicyclo[4.3.0]non-3-ene (33)

To a solution of (+)-**28** contaminated with **i** ((∼4:1) 1 g) in dry THF (60 mL) under an atmosphere of nitrogen at −78 °C, lithium Selectride was added over 2.5 h. The reaction was quenched at −78 °C with satd aq NH_4Cl after 5 h and then

warmed to room temperature and extracted with ethyl acetate. The combined organic layers were washed with brine and dried over $MgSO_4$. The solvent was removed under reduced pressure. The residue was chromatographed on silica gel (petroleum ether/diethyl ether 3:1) yielding unreacted ketone **28** (480 mg), alcohol **ii** (230 mg) and **27** (56 mg). Alcohol **ii** (230 mg) and 140 mg imidazole were dissolved in dry DMF (18 mL) and triethylsilyl chloride (0.26 mL) was added with stirring under an argon atmosphere and stirred at room temperature for 3.5 h. To complete the reaction further, triethylsilyl chloride (0.1 mL) was added and stirring was continued for 2 h. The reaction was quenched with satd aq $NaHCO_3$ (10 mL). The aqueous layer was extracted with ethyl acetate and the combined organic layers were washed with brine and dried over $MgSO_4$. The crude product was purified on silica gel (petroleum ether/diethyl ether 10:1) and isolated as a colourless oil (252 mg, 73%). $[\alpha]_D^{20}$ +47.3 (*c* 1.0, acetone). IR (cm^{-1}, film): 3021, 2954, 2907, 2877, 1414, 1150, 1112, 1044; ^1H NMR (400 MHz, $CDCl_3$) δ (ppm) 0.60 (q, 6H, $Si(CH_2CH_3)_2$, J_{CH_3,CH_2}=7.8), 0.96 (t, 9H, $Si(CH_2CH_3)_2$, J_{CH_2,CH_3}=7.8), 0.97 (d, 3H, $CH_3(8)$, $J_{CH_3,8}$~6), 1.47 (ddd, 1H, H(9), $J_{9,8}$=7.3, *J*=9.6, *J*=12.8), 1.50–1.60 (m, 2H, H(9,6)), 1.73 (m, 1H, H(1), *J*=8.4, *J*=*J*=9.4, *J*=12.4), 2.02–2.20 (m, 4H, H(5,8,5,2)), 3.36 (s, 3H, CH_3O), 3.36 (dd, 1H, H(1′), $J_{1',1'}$=9.35, $J_{1',2}$=7.3), 3.56 (dd, 1H, H(1′), $J_{1',1'}$=9.35, $J_{1',2}$=4.8), 3.99 (t, 1H, H(7), $J_{7,6}$~$J_{7,8}$~3.8), 4.62 (A-part of AB-system, OCH_2O, $J_{A,B}$=6.3), 4.64 (B-part of AB-system, OCH_2O, $J_{A,B}$=6.3), 5.65 (m, 1H, H(3), $J_{3,4}$=9.85, *J*~2.8, *J*~*J*~1.3), 5.79 (m, 1H, H(4), $J_{4,3}$=9.85, *J*=4.8, *J*~*J*~2.3); ^1H NMR (400 MHz, C_6D_6) δ (ppm) 0.715 (q, 6H, $Si(CH_2CH_3)_2$, J_{CH_3,CH_2}=7.8), 1.11 (t, 9H, $Si(CH_2CH_3)_2$, J_{CH_2,CH_3}=7.8), 1.16 (d, 3H, $CH_3(8)$, $J_{CH_3,8}$=5.8), 1.56 (m, 1H, H(6), $J_{6,7}$=3.3, $J_{6,5}$=5.1, $J_{6,5}$=11.1, $J_{6,1}$=11.9), 1.6 (td, 1H, H(9), $J_{9,8}$=2.5, $J_{9,9}$~$J_{9,1}$=9.6), 1.66 (m, 1H, H(9), $J_{9,8}$~7.3, $J_{9,9}$~9.4, $J_{9,1}$=12.8), 1.96–2.11 (m, 3H, H(5,8,1)), 2.33–2.43 (m, 2H, H(5,2)), 3.29 (s, 3H, CH_3O), 3.46 (dd, 1H, H(1′), $J_{1',1'}$=9.35, $J_{1',2}$=7.6), 3.65 (dd, 1H, H(1′), $J_{1',1'}$=9.35, $J_{1',2}$=5.0), 3.93 (t, 1H, H(7), $J_{7,6}$~$J_{7,8}$~3.8), 4.595 (A-part of AB-system, OCH_2O, $J_{A,B}$=6.3), 4.615 (B-part of AB-system, OCH_2O, $J_{A,B}$=6.3), 5.97 (m, 1H, H(4), $J_{4,3}$=9.85, *J*~4.8, *J*~*J*~1.7), 6.01 (m, 1H, H(3), $J_{3,4}$~10.0, *J*~*J*~*J*~1–2); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) 5.9, 77.5, 16.3, 27.1, 36.5, 38.9, 39.5, 45.4, 48.5, 55.5, 71.7, 77.5, 97.0, 129.0, 129.3; MS (EI, 70 eV, 30 °C): 340 (14), 311 (13), 278 (19), 249 (14), 177 (36), 159 (26), 146 (94), 133 (38), 117 (68), 105 (71), 103 (48), 91 (100), 75 (70), 59 (52); HRMS (EI, 70 eV, 30 °C) calcd for $C_{19}H_{36}O_3Si$: 340.2434, found: 340.2439. The large coupling constants of H(6) to H(1) and H(5) establish the *trans* configuration, strong NOESY crosspeaks 6/2, 6/7 and 7/8 establish the relative configuration of C(6), (7) and (8).

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