Published in Helvetica Chimica Acta, Vol. 87: 2245-2265, 2004

Stereospecific Synthesis of Carbanucleotides Designed for Antisense Methodology

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A short stereospecific synthesis of the carbocyclic 2′-deoxynucleoside analogues **36** and **37** (*Schemes 2* and *5*) and **45** and **46** (*Schemes 2* and *6*) starting from optically active 8,9,10-trinorborn-5-en-2-one (**1**) is described. As two functional groups capable to react with each other are present in the same molecule of the synthetic carbanucleosides, the latter can form polymers similar to oligonucleotides.

Introduction. – Since the first report on the specific inhibition of gene expression by an oligonucleotide by *Zamecnik* and *Stephenson* in 1978 [1][2], antisense oligonucleotide methodology has become a promising tool in chemotherapy because of its specificity and manifold applications [3–5]. However, although some naturally occurring phosphodiester oligonucleosides have been shown to inhibit the replication of viruses in cell culture, the key to a wide application of oligonucleotide therapeutics resides in the development of modified oligonucleotides, which should be more resistent to degradation by naturally occurring nucleases. Actually, to achieve the desired biological effects, synthetic oligonucleotides must meet the following requirements: *i*) their half-life in the biological medium must be long enough for the desired action to take place inside the cell; *ii*) they must be able to penetrate the cell membrane to reach their objectives, and *iii*) they must bind strongly enough to the targeted nucleic acid sequence.

In principle, any one of the molecular components of an oligonucleotide (*i.e.*, base, sugar, or phosphodiester backbone) can be modified to obtain an antisense nucleotide with specific affinity to a given segment of the targeted nucleic acid. Among these different kinds of modifications, the replacement of a cycloalkane for the ribose moiety is particularly promising since the synthetic nucleoside analogs – so-called carbanucleosides – are resistent against acids and phosphorylase enzymes that cleave the glycosidic linkage of normal nucleosides. Furthermore, the comparatively higher lipophilicity of carbanucleosides is potentially advantageous for facilitating oral administration and cell-wall penetration [6–9]. On the other hand, since the isolation of (−)-(*S*)-aristeromycin from *Streptomyces citricolor* [10] and (−)-neplanocin A from *Ampullariella regularis* [11], the interest in this class of compounds has grown rapidly, and other carbocyclic analogues of purine and pyrimidine nucleosides have been the subject of a great deal of synthetic and biological study in the last decade.

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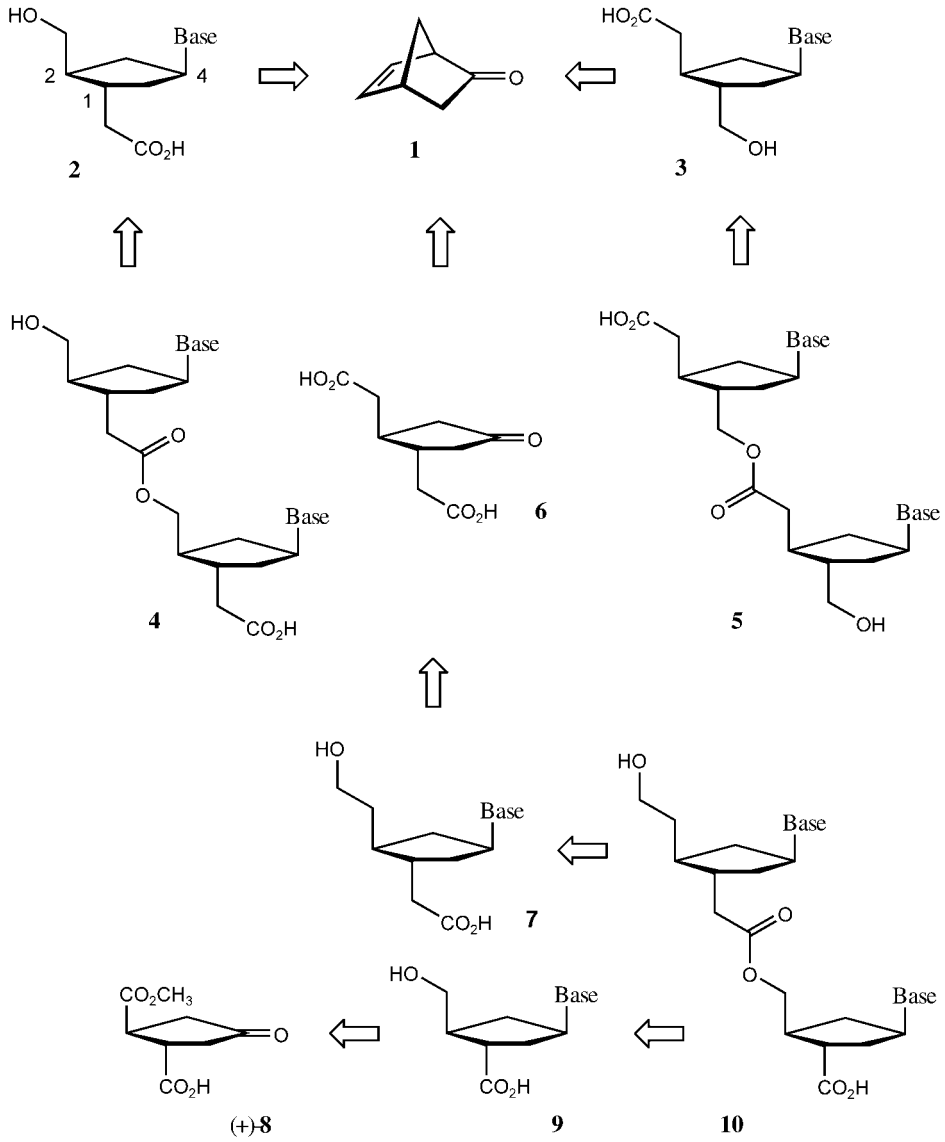
By analogy to the enzymatic synthesis of nucleic acids, a particularly straightforward approach to antisense oligonucleotides is based on the polymerization of monomers containing two functional groups in the same molecule capable to react together in the presence of a catalyst. In making the choice of the most appropriate functional groups that meet this condition, it is obvious to consider first those which lead to macromolecules of the types commonly synthesized in polymer chemistry, *i.e.*, polycarboxylates and polyamides. On the other hand, the length of the chains joining the carbanucleoside units must be appropriate to assure an intramolecular separation between the monomer units in the polymer chain as similar as possible to that present in nucleic acids. As a result of these considerations, the syntheses of three carbadinucleotides of the type **4**, **5**, and **10** were designed, which should be accessible from monomeric building blocks of the type represented by **2**, **3**, **7** (from **6**), and **9** (from (+)-**8**), and **9** (*Scheme 1*).

A straightforward synthesis of *rac*-**2** and *rac*-**3** (both as butyl esters bearing a protecting group at the primary alcohol function) from *rac*-bicyclo[2.2.1]hept-5-en-2-one (*rac*-**1**; short form: norbornenone) was carried out some years ago in our laboratory, affording in a four-step sequence both epimers in an overall yield of 43% each [12]. This approach proved to be more advantageous than an alternative synthesis reported previously by *Jenny et al.*, who obtained the methyl ester of *rac*-**3** in 24% yield in six reaction steps starting from racemic *exo*-norbornene-2-carbaldehyde [13][14]. The present communication describes an improved procedure for the synthesis of enantiomerically pure (+)-norbornenone **1**, as well as stereospecific syntheses of **2** and **7** therefrom. The latter is the appropriate counterpart to carbanucleoside **9** for the construction of carbadinucleotide **10**, as the smallest self-replicating unit suitable for the synthesis of polycarbanucleotides, the length of which should enable hybridization with natural DNA or RNA fragments. Carbanucleoside **9** should be readily accessible from enantiomerically pure (+)-**8**, which has been obtained by enzymatic resolution of the racemate [15]. Ultimately, the syntheses of **2** and **7** described in the present work take advantage of the fact that their common optically active cyclopentanone precursor **6** posses a C_2 symmetry axis, giving rise to a sole enantiomer on reduction of the carbonyl group.

Results and Discussion. – *Synthesis of Carbanucleosides* **45** *and* **46**. *The Concept …* The (1*R*,2*R*)-isomer of **6** should be accessible from (+)-norbornenone **1** by means of the conventional methodology of opening the bicyclo[2.2.1]heptane skeleton by *Baeyer–Villiger* oxidation of the norbornanone derivative **12a** (*Scheme 2*). Thus, the key step of the reaction sequence represented by the framed formulae in *Scheme 2* is the introduction of the acetic acid chain at C(2) of the cyclopentane ring. This goal should be achieved by cyclopropanation of the C=C bond of **1** with a diazoacetate and subsequent regioselective opening of the cyclopropane ring of **11** by cleaving the C–C bond vicinal to the carbonyl group. Depending on the diazocarboxylate used for the cyclopropanation reaction, chemoselective transformation of the ester group of **13** (→ **14**) prior to cleavage of the lactone ring enables to differentiate between both side chains at C(1) and C(2). After cleavage of the lactone ring, the OH group of the obtained hydroxycyclopentanediacetate is *cis* with respect to the acetic acid moiety originating from the norbornenone skeleton (*cf.* **15** in *Scheme 2*) so that nucleophilic

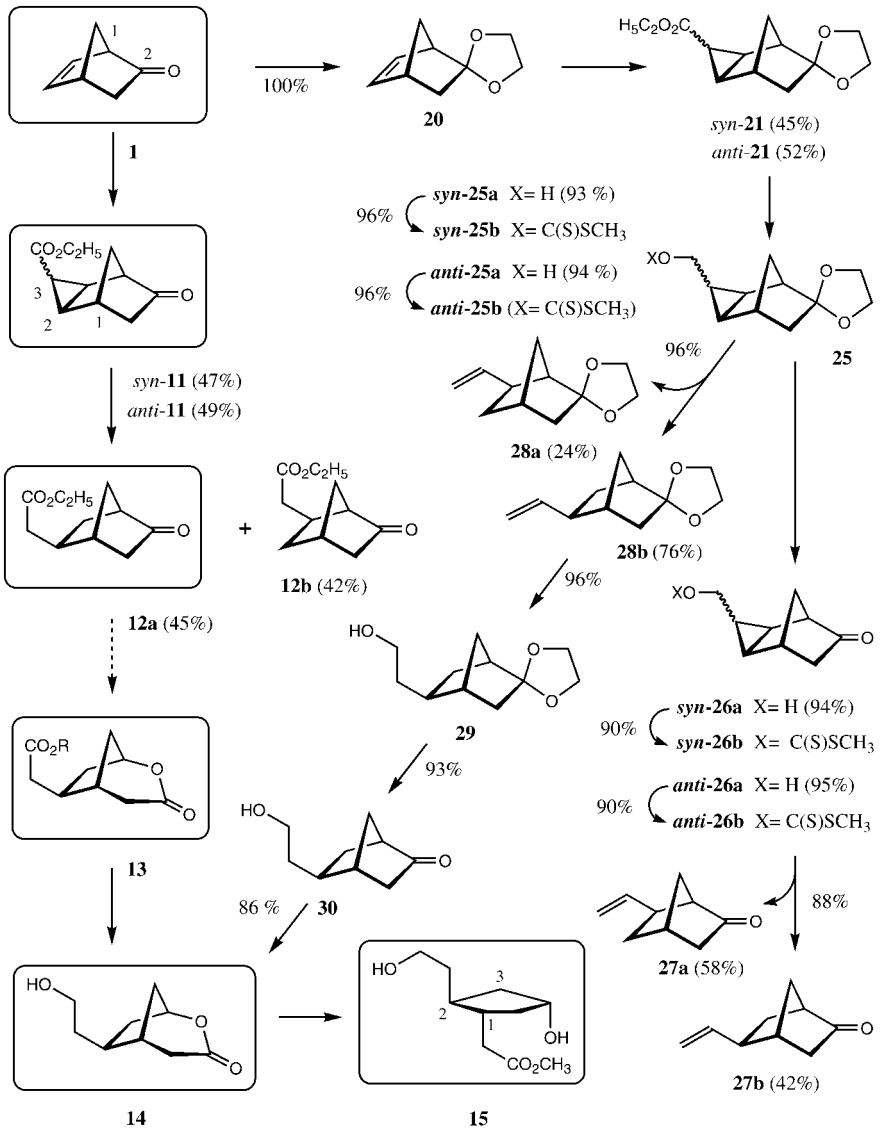
Scheme 1



substitution of the OH group by a nucleobase affords the corresponding carbanucleoside with the nucleobase *cis* to the modified acetic acid chain (*cf.* below, *Scheme 6*).

… *and Its Realization.* (+)-Norbornenone **1** was obtained by asymmetrically catalyzed *Diels–Alder* cycloaddition of α-bromoacrylaldehyde to cyclopentadiene as reported by *Corey* and co-workers [16][17] (*Scheme 3*). In contrast to *Corey*'s method, however, the preparation diol **19** *via* epoxide **18** [18] proved to be more efficient and reproducible than either the direct transformation of bromohydrine **17** [18] into **19** or

Scheme 2[2])



the transformation of **16** into the corresponding cyanohydrine *via* the oxime of the former. Moreover, only negligible quantities of by-products were formed during the synthesis of **18** and **19** (see *Exper. Part*). Finally, diol **19** was transformed into optically pure (e.e. >97%) (+)-norbornenone **1** by oxidation with sodium periodate following the procedure described by *Helmchen* and co-workers [19].

The success of the next reaction step, cyclopropanation of the C=C bond of **1**, is strongly dependent on the catalyst used (see *Table*). Actually, according to *Hubert*'s

Scheme 3

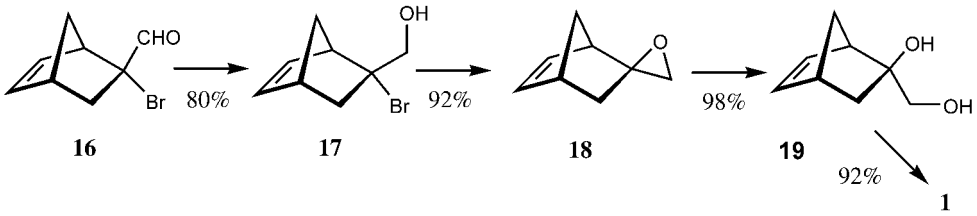


Table. *Dependence of the Yield and* syn/anti *Stereoselectivity of the Cyclopropanation Reaction of* **1** *and* **20** *with Ethyl Diazoacetate* (EDA) *on the Reaction Conditions*

Catalyst	Substrate	Catal./substr. ratio	EDA/substr. ratio[a])	Temp. [°]	Time [h][b])	Yield [%][c])	*anti*/*syn* Ratio [d])
$[Rh_2(OAc)_4]$	**20**	200 : 1	1 : 1	23	1.5	30	1.46
$[Rh_2(OAc)_4]$	**20**	100 : 1	1 : 1	45	1	50	1.80
$[Cu(OTf)_2]$	**20**	100 : 1	1 : 1	23	1.5	38	2.33
$[Cu(OTf)_2]$	**20**	100 : 1	1 : 1	45	1	68	2.41
$[Pd(OAc)_2]$	**20**	100 : 1	1 : 1	23	1.5	83	1.38
$[Pd(OAc)_2]$	**20**	100 : 1	1 : 1	45	1	90	1.16
$[Pd(OAc)_2]$	**20**	50 : 1	1 : 1	45	1	87	1.23
$[Pd(OAc)_2]$	**20**	100 : 1	1.2 : 1	45	1	100	1.16
$[Pd(OAc)_2]$	**1**	100 : 1	1 : 1	45	1	94	1.05
$[Pd(OAc)_2]$	**1**	100 : 1	1.2 : 1	45	1	100	1.05

[a]) A solution of EDA (0.5 mmol) in dry CH_2Cl_2 (12 ml) was added, under Ar, at constant flow rate during 2 h to a stirred solution of the alkene (0.05 mmol) in CH_2Cl_2 (5 ml) containing the catalyst. [b]) Time after the addition of EDA was completed. [c]) Yield of crude product before chromatographic separation. [d]) As determined by ^{1}H-NMR spectroscopy.

study on the mechanism of the reaction of α-diazo esters with olefins [20], catalysts that favor the formation of a metal–olefin complex, which subsequently reacts with the diazo compound, rather than the formation of a metal–carbene complex, reduce the rate of dimerization of the carbenoid equivalent of the diazo compound, which is the main undesired side reaction in this kind of cyclopropane synthesis. Both (+)-norbornenone **1** and ethane-1,2-diyl ketal **20** react in the presence of a palladium catalysts yielding the corresponding cyclopropane derivative in high yield (*Scheme 2*). As expected, carbene addition to the endocyclic C=C-bond takes place from the sterically less-hindered *exo*-side, although it lacks stereoselectivity in terms of the *syn*- or *anti*-position of the carboxylate group with respect to the methano bridge of the bicyclic substrate[2]). In the case of ethane-1,2-diyl ketal **21** the *exo*-configuration of the cyclopropane moiety could be unequivocally demonstrated for both the *syn*- and *anti*-isomer by NMR data.

No nuclear *Overhauser* effect (NOE) on the protons of the $CH_2(8)$ group of the tricycle of *syn*- and *anti*-**21** was observed upon irradiation either of H–C(2) or of H–C(4). As both *syn*- and *anti*-**21** can be transformed by deprotection of the carbonyl group into the corresponding cyclopropanonorbornanone derivatives **11**, the latter

[2]) The designation *syn*/*anti* refers to the position of the substituent at C(3) of the tricycle with respect to the main-bridge atom C(8), *i.e.*, less/more remote from C(8).

must be also *exo*-configurated. Moreover, the assignment of the *syn*- and *anti*-configuration to the isomers of ketal **21** was also possible by NOE difference spectroscopy, since the enhancement by 23.5% of the intensity of the resonance signal at 1.77 ppm assigned to H–C(3) of the tricycle observed on irradiation at H–C(8) of *anti*-**21** requires a '*cis*'-arrangement of the involved H-atoms. On the other hand, the measured coupling constants (^3J(H,H) = 2.6 Hz) between H–C(3) and H–C(2) or H–C(4) are consistent with a *trans*-arrangement of the coupling protons in *anti*-**21** (a corresponding *cis*-arrangement usually results in ^3J(H,H) = 10 ± 2 Hz) [21].

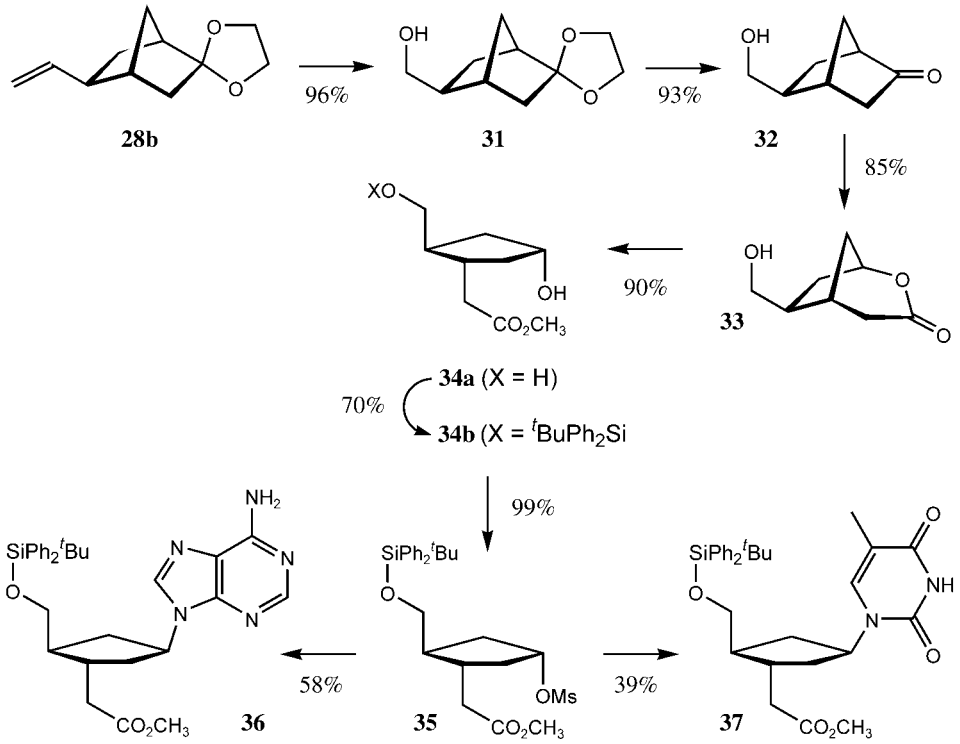
Unfortunately, however, reductive cleavage of the cyclopropane ring, which was attempted by catalytic hydrogenation of the mixture of *syn*- and *anti*-stereoisomers of **11** (both as racemates), was not regioselective: the reaction product consisted of a mixture of the desired 5-oxonorbornane-2-acetate *rac*-**12a** and its isomer *rac*-**12b** in a ratio of roughly 1:1 (*Scheme 2*). In view of this difficulty, we next attempted a regioselective cleavage of the cyclopropane ring in consideration of the well-known tendency of cyclopropylmethyl radicals to isomerize, yielding butene radicals [22]. As a matter of fact, rearrangement of the cyclopropylmethyl radical **22**, derived from **11**, may produce the two radicals **23** and **24**, **23** being homoconjugated with the carbonyl group of the norbornanone skeleton (*Scheme 4*). Although, *a priori*, the preparation of radical **27** does not require the separation of *syn*- and *anti*-**11** since the cyclopropane-ring opening cancels the chirality of its C(2) atom, the following transformations were carried out with the separated stereoisomers, thereby simplifying the characterization of the obtained products. Thus, the ester groups of the ketals *syn*- and *anti*-**21** were reduced with $LiAlH_4$ to yield the primary alcohols *syn*- and *anti*-**25a**, respectively (*Scheme 2*). Following deprotection of the carbonyl group led to the corresponding hydroxy ketones *syn*- and *anti*-**26a**, respectively, which were transformed subsequently into the corresponding xanthates *syn*- and *anti*-**26b**. Radical-induced deoxygenation of the latter (*cf.* [23]) led to a mixture of the 6- and 5-vinylnorbornanones **27a** and **27b**, respectively, with a low preference (58 *vs.* 42%) for the undesired isomer **27a**. This result agrees with the calculated heats of formation of radicals centered at the C(5) and C(6) atoms of norcamphor (= bicyclo[2.2.1]heptane-2-one), which are practically identical within the margin of error of the MNDO method [24]. On the contrary, radical-induced deoxygenation of the xanthates *syn*- and *anti*-**25b**, derived from the ketals *syn*- and *anti*-**25a**, respectively, proceeded with a marked preference for the 5-vinyl isomer **28b**, which was obtained in a 3:1 ratio with respect to the (undesired) 6-vinyl isomer **28a**. Although not completely regioselective, the above reaction sequence provides access (*via* **29** and **30**) to hydroxy lactone **14** as a single isomer that could be transformed in two steps into the desired carbanucleosides **45** and **46** (*cf.* below, *Scheme 6*).

Stereospecific Synthesis of Carbanucleosides **36** *and* **37**. Moreover, vinyl derivative **28b** serves as an intermediate for the synthesis of carbanucleosides **36** and **37**

Scheme 4

23 **22** **24**

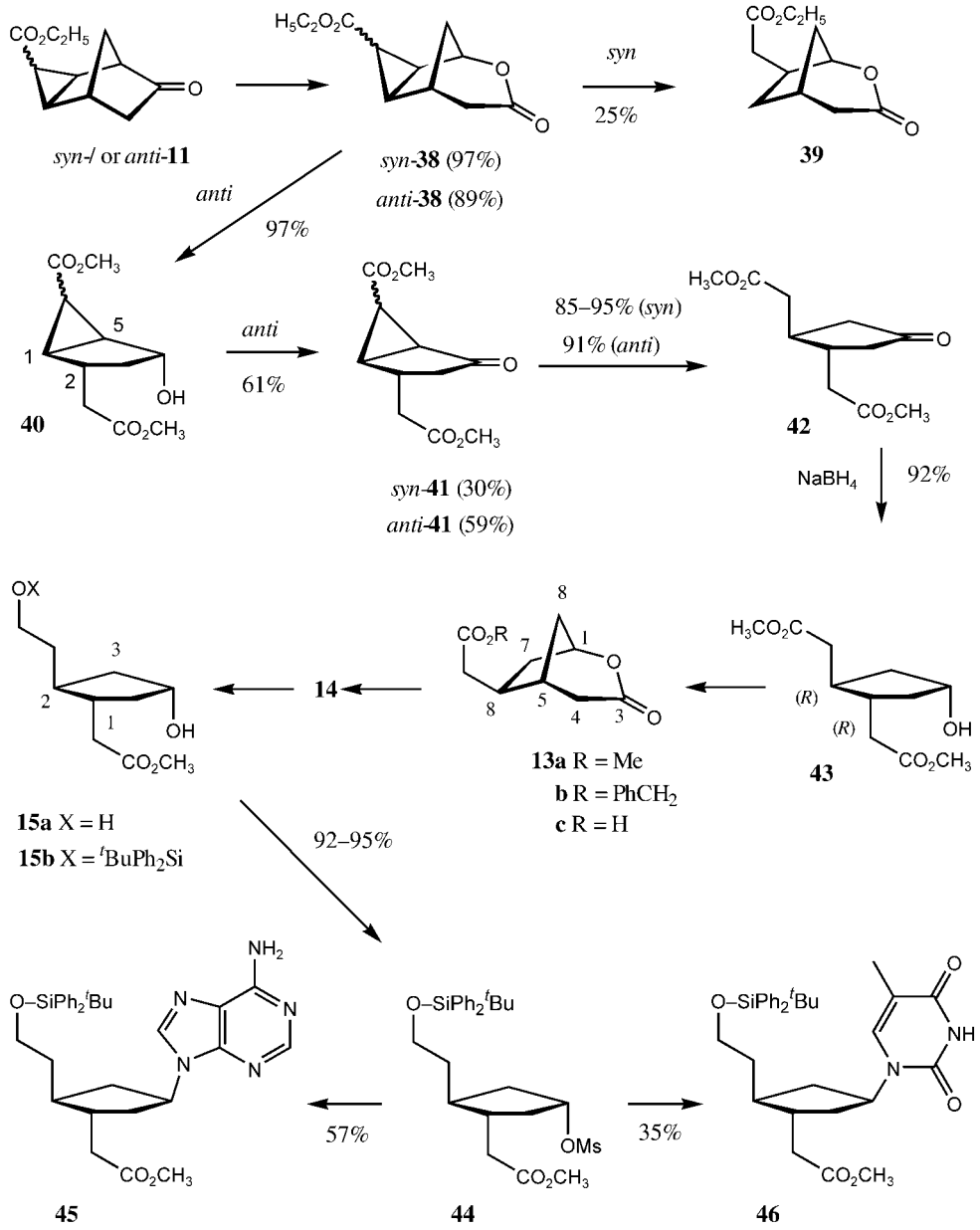
Scheme 5



(*Scheme 5*) as it can be easily transformed by ozonolysis and subsequent reduction of the obtained aldehyde into **31**, the methanol analogue of ethanol **29**. Thus, after deprotection of the carbonyl group, *Baeyer–Villiger* oxidation of the norcampher derivative **32** afforded hydroxy lactone **33**, which was transformed by methanolysis into the hydroxy cyclopentaneacetate **34a**. Following the usual procedure, the primary-alcohol group of **34a** was selectively protected as (*tert*-butyl)diphenylsilyl ether **34b** and, after transformation of the secondary-alcohol group into the corresponding mesylate (→ **35**), the latter was reacted either with adenine or with thymine to yield the corresponding carbanucleosides **36** and **37**, respectively. The same compounds (bearing different protecting groups for the primary-alcohol and carboxylic acid functions) had been obtained earlier, as racemates, by a different route [12].

Stereospecific Synthesis of Carbanucleosides **45** *and* **46**. The unsatisfactory regioselectivity observed in our attempts to cleave the cyclopropane ring of **11** and **25b** by catalytic hydrogenation and radical-induced deoxygenation, respectively, prompted us to postpone the ring opening to the next step of the originally intended reaction sequence, namely the *Baeyer–Villiger* oxidation of the carbonyl group of **11** (*Scheme 6*). However, when lactone *syn*-**38** was hydrogenated on Pd/C, only a low yield (25%) of the undesired ring-opened isomer **39** was obtained, probably due to the competitive reduction of the lactone moiety under these reaction conditions.

Scheme 6[2])



According to a study of the regioselectivity of reductive cleavage of the cyclopropane ring by *Musso* and co-workers [25][26], electron-withdrawing substituents weaken the C–C bond adjacent to the substituted C-atom, thus facilitating its hydrogenolytic cleavage. Thus, it appeared advantageous to modify the proposed

synthetic pathway including ketones *syn*- and *anti*-**41** as intermediates (*Scheme 6*). Both bicyclo[3.1.0]hexanones were readily accessible by oxidation of the corresponding secondary alcohols *syn*- and *anti*-**40**, respectively. The latter were obtained on methanolysis of the lactone moiety of *syn*- and *anti*-**38**, which took place under transesterification of the carboxylate group at the cyclopropane ring. As expected, hydrogenolytic cleavage of the cyclopropane ring of both *syn*- and *anti*-**41** occurred at the σ-bond adjacent to the carbonyl group yielding the C_2-symmetric cyclopentanone derivative **42** regioselectively. Racemic **42** (as the diethyl ester) has previously been prepared in four steps starting with cyclopent-2-enone (*cf.* [27][28]). Borohydride reduction of **42** afforded the desired secondary alcohol **43** as a single isomer. It must be pointed out that this outcome of the synthesis of **43** confirms unequivocally the relative *trans*-configuration at the C(1) and C(2) atoms, since a *cis*-isomer resulting from an *endo*-cyclopropanonorbornanone derivative would afford two diastereomeric cyclopentanol derivatives with opposite configuration at the pseudoasymmetric C(4) atom.

A manifest advantage of the above synthetic strategy is the C_2 symmetry of intermediate **42**, which prevents the formation of stereoisomers on replacement of the carbonyl group by a tetragonal C-atom. Moreover, the same strategy offers a simple possibility to differentiate between the two acetic acid chains at C(1) and C(2), since lactonization of **43** yields a single product, **13a**, which, on transesterification with benzylic alcohol and subsequent hydrogenolysis of the benzyl ester group, affords the monocarboxylic acid **13c** (*Scheme 6*). Diborane reduction of the carboxylic acid group of **13c** took place chemoselectively, thus yielding the primary alcohol **14**, which was finally transformed into **15a** by methanolysis of the lactone ring. After protecting the primary alcohol function of **15a**, the resulting silyl ether **15b** was transformed with methanesulfonyl chloride to the mesylate **44**, which was subjected to nucleophilic substitution with either adenine or thymine to yield the carbanucleosides **45** and **46**, respectively.

Conclusions. – In summary, the present work describes a straightforward stereospecific synthesis of the four carbanucleosides **36**, **37**, **45**, and **46** from optical active norbornen-2-one **1** as a readily accessible starting material. As in each carbanucleoside the two functional groups (OH and COOH) can be deprotected selectively, the monomeric building blocks are suitable for the direct synthesis of polyester analogs of nucleotides or, alternatively, for the stepwise synthesis of heteromeric polynucleotide analogs.

Financial support of this work by the *Swiss National Science Foundation* (Project No. 20-49507.96) is gratefully acknowledged. NMR Spectra were recorded by *F. Fehr*.

Experimental Part

General. Solvents were generally dried and distilled prior to use. All air- and H_2O-sensitive reactions were carried out under Ar. The 3-chloroperbenzoic acid (MCPBA), *N*,*N*-dimethylpyridin-4-amine (DMAP), tetrahydrofuran (THF), pyridinium chlorochromate (PCC), and other reagents were purchased from *Fluka Chemie AG*, CH-9471 Buchs. TLC (reaction monitoring): *E. Merck* silica-gel *60* F_{254} (0.2 mm) precoated aluminium plates (20 × 20 cm); detection by UV light (254 and 366 nm) or 1% aq. 2,4-dinitrophenylhydrazine soln. (prepared by dissolving 0.4 g of 2,4-dinitrophenylhydrazine in 100 ml of 2N HCl), or alkaline $KMnO_4$ soln. (prepared by dissolving 3 g of $KMnO_4$ and 20 g of K_2CO_3 in 300 ml of H_2O, followed by addition of 3 ml of 5%

aq. NaOH soln.). Column chromatography (CC) and flash column chromatography (FC): silica gel *60* (0.063–0.200 mm, 700–230 mesh) and silica gel *60* (0.040–0.063 mm, 230–400 mesh), respectively, from *E. Merck AG*.

M.p.s: *Kofler* hot-stage apparatus (*Thermovar, C. Reichert AG*, Vienna) equipped with a digital thermometer; uncorrected. Optical rotations $[\alpha]_D$: *Perkin-Elmer-241-MV* polarimeter; in deg ml g^{-1} dm^{-1}), *c* in g/100 ml. UV/VIS Spectra: *Hewlett-Packard-8452A* diode array spectrophotometer; λ_{max} (ε) in nm. IR Spectra: *Mattison 5000 FT-IR*; $\tilde{\nu}$ in cm^{-1}. NMR Spectra: *Varian-Gemini-200* (200.00 (^{1}H) and 50.30 MHz (^{13}C)), *Bruker-AM-360* (360.14 (^{1}H) and 90.57 MHz (^{13}C)), and *Bruker-Advance-DRX-500* (500.13 (^{1}H) and 125.76 MHz (^{13}C)) spectrometer; $CDCl_3$ solns., when not given otherwise; chemical shifts δ in ppm rel. to Me_4Si as internal standard, *J* values in Hz; assignments based on homonuclear COSY; ^{1}H{^{1}H}NOE difference correlations attached proton test (APT) and/or chemical shifts; NOE: indication of δ of enhanced signal (% enhancement, irradiated δ). MS: *Vacuum Generator Micromass 7070 E*; EI (electron ionization) at 70 eV; in *m*/*z* (rel. %). High-resolution (HR) MS: *Bruker 4.7T-BioApexII* (FT-MS). Combustion analyses were carried out by *Ilse Beetz*, *Microanalytical Laboratory*, Kronach, Germany.

*(+)-(1*R*,4*R*)-Bicyclo[2.2.1]hept-5-en-2-one* (**1**). Oxidation of **19** with sodium periodate according to [19] gave **1**. Colorless oil. $[\alpha]_D^{26} = +1107.2$ ($c = 0.41$, $CHCl_3$) ([29]: $[\alpha]_D^{23} = +1033$ ($c = 1.01$, $CHCl_3$)).

*Ethyl (1*R*,2*R*,3*R*,4*R*,5*R*)- and (1*R*,2*R*,3*S*,4*R*,5*R*)-6-Oxotricyclo[3.2.1.0^{2,4}]octane-3-carboxylate* (*syn*- and *anti*-**11**). A mixture of **1** (9.73 g, 90 mmol) (*cf.* [19]) and $[Pd(OAc)_2]$ (202 mg, 0.9 mmol) in dry freshly distilled CH_2Cl_2 (400 ml) was stirred at high speed and heated to rapid reflux in a round-bottomed flask equipped with a high-dilution adapter (*Aldrich®*, *Z 22,330-1*) while a soln. of ethyl diazoacetate (92%; 13.4 g, 108 mmol) in CH_2Cl_2 (400 ml) was added dropwise at a rate of 1/20 of the refluxing flow. After the addition was complete (4 h), the mixture was refluxed for additional 2 h. The residue obtained after evaporation was separated by FC (silica gel, AcOEt/petroleum ether 1:4): 8.15 g (47%) of *syn*-**11** (R_f 0.31) and 8.64 g (49%) of *anti*-**11** (R_f 0.44), both as colorless oils.

Data of syn-**11**: $[\alpha]_D^{21} = +274.1$ ($c = 0.63$, $CHCl_3$). IR ($CHCl_3$): 1746, 1724. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.18 (*q*, *J* = 7.13, MeC*H*$_2$O); 2.86 (*m*, 1 H); 2.84 (*m*, 1 H); 2.09 (*ddm*, *J* = 17.06, 3.50, 1 H–C(7)); 2.00 (*dd*, *J* = 17.06, 4.54, 1 H–C(7)); 1.81 (*dd*, *J* = 7.72, 7.66, H–C(3)); 1.53 (*ddm*, *J* = 7.72, 6.49, 1 H); 1.35 (*ddm*, *J* = 7.66, 6.49, 1 H); 1.29 (*t*, *J* = 7.13, *Me*CH$_2$O); 1.24 (*dm*, *J* = 12.65, 1 H–C(8)); 1.16 (*dm*, *J* = 12.65, 1 H–C(8)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 212.92 (C(6)); 171.09 (CO); 61.03 (MeCH$_2$O); 48.40 (C(5)); 44.39 (C(7)); 34.97 (C(1)); 27.65 (C(8)); 25.81 (C(3)); 23.17 (C(2)); 16.23 (C(4)); 13.97 (*Me*CH$_2$O). CI-MS (CH_4): 223 (7, $[M+29]^+$), 196 (12, $[M+2]^+$), 195 (100, $[M+1]^+$), 177 (2), 167 (5), 166 (5), 149 (47), 121 (22), 95 (4), 93 (3), 79 (5). Anal. calc. for $C_{11}H_{14}O_3$: C 68.02, H 7.27; found: C 67.96, H 7.31.

Data of anti-**11**: $[\alpha]_D^{20} = +303.9$ ($c = 0.80$, $CHCl_3$). IR ($CHCl_3$): 1744, 1724. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.13 (*q*, *J* = 7.14, MeC*H*$_2$O); 2.70–2.73 (*m*, H–C(1), H–C(5)); 2.09 (*dd*, *J* = 2.60, 2.46, H–C(3)); 2.05–2.03 (*m*, 2 H–C(7)); 1.75 (*dm*, *J* = 7.20, 1 H); 1.57 (*dm*, *J* = 7.00, 1 H); 1.30 (*m*, 1 H–C(8)); 1.26 (*t*, *J* = 7.14, 3 *Me*CH$_2$O); 1.21 (*dm*, *J* = 11.81, 1 H–C(8)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 212.68 (C(6)); 171.95 (CO); 60.73 (MeCH$_2$O); 48.05 (C(5)); 43.28 (C(7)); 34.48 (C(1)); 26.94 (C(8)); 26.07 (C(2)); 19.95 (C(3)); 19.59 (C(4)); 14.17 (*Me*CH$_2$O). CI-MS (CH_4): 223 (10, $[M+29]^+$), 195 (100, $[M+1]^+$), 194 (19, M^+), 166 (11), 165 (2), 149 (52), 121 (13), 93 (3), 79 (3). EI-MS: 195 (2, $[M+1]^+$), 194 (11, M^+), 166 (14), 165 (6), 149 (10), 148 (20), 121 (26), 120 (48), 119 (23), 93 (33), 91 (68), 79 (100), 78 (40), 77 (72), 65 (18), 51 (20), 39 (42). Anal. calc. for $C_{11}H_{14}O_3$: C 68.02, H 7.27; found: C 67.63, H 7.27.

Ethyl 5-Oxobicyclo[2.2.1]heptane-2-acetate (*rac*-**12a**) *and Ethyl 6-Oxobicyclo[2.2.1]heptane-2-acetate* (*rac*-**12b**). A soln. of racemic *syn*-**11** (550 mg, 2.83 mmol) in MeOH (30 ml) was hydrogenated at r.t./1 atm over 10% Pd/C (204 mg) for 40 h. Then the catalyst was filtered off, the filtrate evaporated, and the residue subjected to CC (silica gel, AcOEt/petroleum ether 1:16): 250 mg (45%) of *rac*-**12a** and 233.3 mg (42%) of *rac*-**12b** as colorless oils.

Data of rac-**12a**: ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.18 (*q*, *J* = 7.16, MeC*H*$_2$O); 2.59 (*m*, 1 H); 2.46 (*m*, 1 H); 2.44 (*dd*, *J* = 15.49, 8.00, 1 H); 2.33 (*dd*, *J* = 15.49, 7.58, 1 H); 2.19 (*ddd*, *J* = 15.92, 7.96, 4.92, 1 H); 2.11 (*dd*, *J* = 17.85, 4.63, 1 H); 1.98 (*ddd*, *J* = 17.85, 3.56, 0.97, 1 H); 1.84 (*ddd*, *J* = 13.30, 8.32, 1.41, 1 H); 1.70–1.68 (*m*, 2 H); 1.40 (*ddd*, *J* = 13.30, 4.80, 4.80, 1 H); 1.27 (*t*, *J* = 7.16, *Me*CH$_2$O). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 217.07 (C(5)); 172.22 (CO); 60.45 (MeCH$_2$O); 50.25 (C(4)); 45.37 (C(6)); 40.87 (CH$_2$COOEt); 40.03 (C(2)); 36.57 (C(1)); 34.57, 31.54 (C(3), C(7)); 14.22 (*Me*CH$_2$O). CI-MS (CH_4): 237 (4, $[M+41]^+$), 225 (14, $[M+29]^+$), 198 (14, $[M+2]^+$), 197 (100, $[M+1]^+$), 169 (6), 168 (4), 151 (10), 123 (4).

Data of rac-**12b**: ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.14 (*q*, *J* = 7.16, MeC*H*$_2$O); 2.70 (*m*, H–C(2)); 2.44–2.26 (*m*, 4 H); 2.06 (*dm*, *J* = 17.84, 1 H); 1.86 (*dd*, *J* = 17.84, 3.96, 1 H); 1.82 (*ddd*, *J* = 12.57, 7.48, 2.15, 1 H); 1.72 (*dm*, *J* = 11.12, 1 H, H–C(7)); 1.67 (*dm*, *J* = 11.12, 1 H–C(7)); 1.40 (*dm*, *J* = 12.57, 1 H); 1.26 (*t*, *J* = 7.16, *Me*CH$_2$O). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 216.52 (C(6)); 171.76 (CO); 60.53 (MeCH$_2$O); 54.60 (C(1)); 44.22

(C(5)); 39.82 (CH_2COOEt); 35.78 (C(4)); 35.63, 34.62 (C(3), C(7)); 32.94 (C(2)); 14.20 ($Me$$CH_2$O). CI-MS ($CH_4$): 237 (4, $[M+41]^+$), 225 (12, $[M+29]^+$), 198 (11, $[M+2]^+$), 197 (97, $[M+1]^+$), 179 (4), 169 (5), 168 (18), 153 (14), 152 (13), 150 (100), 123 (4), 79 (3).

*Methyl (1*R,*5*R,*6*R*)-2-Oxa-3-oxobicyclo[3.2.1]octane-6-acetate* (**13a**). A mixture of **43** (200 mg, 86.8 mmol) and Pb_3O_4 (3 mg) was heated at 190–200°/200 mbar for 1 h. Then the mixture was bulb-to-bulb distilled at 0.1 mbar, and the thus obtained crude product (155 mg, 90%) was recrystallized from hexane/Et_2O: 110 mg (64%) of **13a**. Colorless crystals. M.p. 78–79.5°. $[\alpha]_D^{20} = +18.0$ ($c = 0.521$, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): 4.85 (m, H–C(1)); 3.69 (s, MeO); 2.75 (dd, $J = 18.50, 5.02$, 1 H–C(4)); 2.61 (ddd, $J = 18.62, 2.06, 2.06$, 1 H–C(4)); 2.53–2.42 (m, CH_2); 2.40–2.25 (m, 1 H–C(7), H–C(6), H–C(5)); 1.94 (dm, $J = 13.13$, 1 H–C(8)); 1.79 (dm, $J = 13.14$, 1 H–C(8)); 1.55–1.47 (m, 1 H–C(7)). ^{13}C-NMR (APT): 172.76, 170.21, (2 CO); 81.30 (C(1)); 52.11 (MeO); 41.24, 40.68, 40.19 (C(4), C(7), C(8)); 39.05 (C(5)); 37.37 (C(6)); 33.66 (CH_2). EI-MS: 199 (37, $[M+1]^+$), 181 (100), 167 (16), 153 (17), 139 (28). HR-ESI-MS: 221.0783 ($[M+Na]^+$, $C_{10}H_{14}O_4Na^+$; calc. 221.0784).

*Benzyl (1*R,*5*R,*6*R*)-2-Oxa-3-oxobicyclo[3.2.1]octane-6-acetate* (**13b**). A soln. of benzyl alcohol (11 mg, 0.10 mmol) in dry THF (3 ml) was cooled to 0° before 1.6M BuLi in hexane (65 µl) was added. After 10 min stirring, the mixture was added dropwise to a stirred soln. of **13a** (20 mg, 0.10 mmol) in dry THF (5 ml) at 0°. Stirring was continued for 2 h at 0° before the mixture was poured into H_2O (50 ml) and extracted with CH_2Cl_2. The combined org. phase was dried (Na_2SO_4) and evaporated and the residue purified by prep. TLC (AcOEt/hexane 1:1): 7.5 mg (27%) of **13b**. Colorless oil. ^{1}H-NMR ($CDCl_3$): 7.40–7.31 (m, 5 arom. H); 5.14 (A of AB, $J = 12.21$, 1 H, PhCH_2); 5.10 (B of AB, $J = 12.21$, 1 H, PhCH_2); 4.83 (m, H–C(1)); 2.71 (dd, $J = 18.62, 4.89$, 1 H–C(4)); 2.56 (ddd, $J = 18.61, 2.14, 2.14$, 1 H–C(4)); 2.52–2.43 (m, CH_2); 2.42–2.22 (m, 1 H–C(7), H–C(6), H–C(5)); 1.91 (dm, $J = 13.12$, 1 H–C(8)); 1.76 (dm, $J = 13.13$, 1 H–C(8)); 1.55–1.45 (m, 1 H–C(7)). ^{13}C-NMR (APT): 171.73, 169.86 (2 CO); 135.63 (arom. C); 128.67, 128.57, 128.48, 128.37, 128.27 (5 arom. CH), 80.95 (C(1)); 66.54 (PhCH_2); 40.89, 40.64, 39.86 (C(4), C(7), C(8)); 38.79 (C(5)); 37.02 (C(6)); 33.33 (CH_2). HR-ESI-MS: 297.1093 ($[M+Na]^+$, $C_{16}H_{18}O_4Na^+$; calc. 297.1097).

*(1*R,*5*R,*6*R*)-2-Oxa-3-oxobicyclo[3.2.1]octane-6-acetic Acid* (**13c**). A stirred soln. of **13b** (7.5 mg, 0.027 mmol) in AcOEt (1 ml) was hydrogenated over 10% Pd/C (2 mg) at r.t./1 atm until the uptake of H_2 ceased (1 h). The catalyst was filtered off, the filtrate evaporated, and the residue recrystallized from Et_2O/hexane: 3 mg (60%) of **13c**. Colorless crystals. M.p. 123–125°. ^{1}H-NMR ($CDCl_3$): 10.3 (br. s, COOH); 4.86 (m, H–C(1)); 2.76 (dd, $J = 18.58, 4.89$, 1 H–C(4)); 2.62 (ddd, $J = 18.58, 1.96, 1.96$, 1 H–C(4)); 2.56–2.45 (m, CH_2); 2.43–2.28 (m, 1 H–C(7), H–C(6), H–C(5)); 1.96 (dm, $J = 13.20$, 1 H–C(8)); 1.80 (dm, $J = 13.20$, 1 H–C(8)); 1.57–1.50 (m, 1 H–C(7)). ^{13}C-NMR (APT): 176.88 (COOH); 169.88 (CO); 80.91 (C(1)); 40.89, 40.09, 39.88 (C(4), C(7), C(8)); 38.47 (C(5)); 37.06 (C(6)); 33.32 (CH_2). HR-ESI-MS: 207.0622 ($[M+Na]^+$, $C_9H_{12}O_4Na^+$; calc. 207.0627).

*(1*R,*5*R,*6*R*)-6-(2-Hydroxyethyl)-2-oxabicyclo[3.2.1]octan-3-one* (**14**). *a*) A soln. of **13c** (3 mg, 0.016 mmol) in dry THF (2 ml) was cooled to 0° before 1M BH_3 in THF (70 µl) was added. The mixture was stirred for 7 h at 0°, then diluted with H_2O (1 ml) and shaken with CH_2Cl_2 (10 ml). The org. layer was dried (Na_2SO_4) and evaporated, and the residue purified by prep. TLC (AcOEt/hexane/EtOH 10:10:1): 1.3 mg (47%) of **14**). Colorless oil.

b) A mixture of **30**, (5.18 g, 33.6 mmol), $NaHCO_3$ (5.65 g, 67.2 mmol), and *ca.* 55% MCPBA (21.14 g, 67.2 mmol) in CH_2Cl_2 (460 ml) was stirred at r.t. until the starting material had completely disappeared (*ca.* 2 h, TLC monitoring). The mixture was then filtered, the solid washed with CH_2Cl_2, and the combined filtrate shaken several times with small volumes of cold 10% aq. Na_2SO_3 soln. until the starch/I_2 test of the org. layer was negative. Then the combined aq. phase was extracted with CH_2Cl_2 (6 × 100 ml), the combined org. soln. dried (Na_2SO_4) and evaporated, and the residue purified by CC (AcOEt/CH_2Cl_2/EtOH 10:10:1): 4.92 g (86%) of **14**. R_f 0.39. Colorless oil. $[\alpha]_D^{20} = +31.9$ ($c = 1.88$, $CHCl_3$). IR ($CHCl_3$): 1726. ^{1}H-NMR ($CDCl_3$): 4.85 (m, H–C(1)); 3.72–3.62 (m, CH_2CH_2OH); 2.74 (dd, $J = 18.48, 5.03$, 1 H–C(4)); 2.55 (ddd, $J = 18.57, 2.09, 2.09$, 1 H–C(4)); 2.44 (ddd, $J = 14.91, 8.60, 2.65$, 1 H–C(7)); 2.27 (m, H–C(5)); 2.14 (m, H–C(6)); 1.93 (dm, $J = 13.08$, 1 H–C(8)); 1.80 (dm, $J = 13.00$, 1 H–C(8)); 1.68 (m, 1 H, CH_2CH_2OH); 1.58 (br. s, 1 H, CH_2CH_2OH); 1.55–1.47 (m, 2 H, 1 H–C(7), CH_2CH_2OH). ^{13}C-NMR (APT): 170.25 (CO); 81.14 (C(1)); 61.18 (CH_2CH_2OH); 41.17 (C(4)); 40.27 (CH_2CH_2OH); 39.30 (C(7)); 39.04 (C(6)); 37.08 (C(5)); 33.48 (C(8)). EI-MS: 171 (23, $[M+1]^+$), 153 (63), 135 (21), 125 (24), 111 (100), 107 (27), 93 (49), 81 (10), 79 (10), 67 (6), 61 (10). HR-ESI-MS: 193.0836 ($[M+Na]^+$, $C_9H_{14}O_3Na^+$; calc. 193.0835).

*Methyl (1*R,*2*S,*4*S*)-4-Hydroxy-2-(2-hydroxyethyl)cyclopentaneacetate* (**15a**). A soln. of **14** (5.8 g, 34 mmol) in MeOH (200 ml) containing 37% aq. HCl soln. (1.9 ml, 23 mmol) was refluxed for 20 h and then cooled, before 10% aq. $NaHCO_3$ soln. (40 ml) was added. The resulting mixture was extracted with AcOEt (8 × 100 ml), the

combined org. extract dried (Na_2SO_4) and evaporated, and the slightly yellow oil (6.19 g, *ca.* 90%) was used without further purification for the next step. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.34 (*m*, H−C(4)); 3.74–3.61 (*m*, $HOCH_2CH_2OH$); 3.68 (*s*, MeO); 2.60 (*dd*, *J* = 15.66, 4.86, 1 H, CH_2CO_2Me); 2.36 (*dd*, *J* = 15.66, 8.18, 1 H, CH_2CO_2Me); 2.29 (*ddd*, *J* = 14.02, 8.51, 6.01, 1 H); 1.99–1.93 (*m*, 2 H); 1.91 (*m*, 1 H); 1.79 (*m*, 1 H); 1.68 (br., 2 OH); 1.49–1.40 (*m*, 2 H); 1.37 (*dddd*, *J* = 13.96, 7.08, 3.48, 1.67, 1 H). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 173.88 (CO); 72.50 (C(4)); 61.75 (CH_2CH_2OH); 51.51 (MeO); 42.34, 41.62 (C(3), C(5)); 40.55, 39.61 (C(1), C(2)); 39.20 (CH_2CH_2OH); 37.46 (CH_2CO_2Me). CI-MS (CH_4): 231 (13, $[M+29]^+$), 217 (1, $[M+15]^+$), 203 (17, $[M+1]^+$), 201 (2, $[M-1]^+$), 185 (47), 171 (7), 168 (13), 167 (100), 153 (87), 135 (47), 125 (16), 111 (56), 107 (34), 93 (26).

*Methyl (1*R,2S,*4*S*)-2-{2-{[(*tert*-*Butyl)diphenylsilyl]oxy}ethyl}-4-hydroxycyclopentaneacetate* (**15b**). A soln. of **15a** (6.27 g, 31 mmol) in anh. DMF (60 ml) containing 1*H*-imidazole (5.28 g, 77.5 mmol), and (*tert*-butyl)chlorodiphenylsilane (10.23 g, 37.2 mmol) was stirred for 40 h at r.t. and then poured into AcOEt (1.2 l). The resulting soln. was shaken successively with 1M HCl (12 ml), H_2O (120 ml) and sat. aq. $NaHCO_3$ soln. (120 ml), dried (Na_2SO_4) and evaporated and the residue purified by FC (AcOEt/CH_2Cl_2 1:8): 11.1 g (74% from **15a**) of **15b** (R_f 0.44). Colorless syrup. $[\alpha]_D^{23} = +27.1$ (*c* = 0.78, $CHCl_3$). IR ($CHCl_3$): 1728. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.68–7.63 (*m*, 4 arom. H); 7.46–7.35 (*m*, 6 arom. H); 4.27 (*m*, H−C(4)); 3.74–3.59 (*m*, CH_2CH_2O); 3.66 (*s*, MeO); 2.56 (*dd*, *J* = 15.75, 4.36, 1 H, CH_2CO_2Me); 2.34–2.21 (*m*, 2 H); 1.96–1.74 (*m*, 4 H); 1.67 (br., OH); 1.41–1.29 (*m*, 3 H); 1.04 (*s*, *t*Bu). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 173.68 (CO); 135.51, 133.91, 129.52, 127.56 (12 arom. C); 72.38 (C(4)); 62.85 (CH_2CH_2O); 51.37 (MeO); 42.25, 41.56 (C(3), C(5)); 40.63, 39.66 (C(1), C(2)); 39.02 (CH_2CH_2OH); 37.23 (CH_2CO_2Me); 26.83 (Me_3C); 19.11 (Me_3C). FAB-MS: 463 (6, $[M+Na]^+$), 441 (7, $[M+1]^+$), 423 (2), 383 (56), 363 (22), 345 (20), 319 (4), 305 (3), 273 (8), 253 (7), 239 (11), 213 (73), 199 (100), 183 (52), 167 (60), 153 (36), 135 (100), 121 (50). Anal. calc. for $C_{26}H_{36}O_4Si$: C 70.87, H 8.23; found: C 71.14, H 8.03.

*Ethyl (1′*R,*2′*R,*3′*R,*4′*R,*5′*R*)- and (1′*R,*2′*R,*3′*S,*4′*R,*5′*R*)-Spiro[1,3-dioxolane-2,6′-tricyclo[3.2.1.0^{2,4}]octane]-3′-carboxylate* (*syn*- and *anti*-**21**). A soln. of **20** (83.70 g, 0.55 mol; $[\alpha]_D^{23} = +168.2$ (*c* = 0.85, $CHCl_3$); prepared like the racemate [30][31]) in dry, freshly distilled CH_2Cl_2 (750 ml) was treated in the presence of [$Pd(OAc)_2$] (1.23 g, 5.54 mmol) with a soln. of 92% ethyldiazoacetate 81.90 g, 0.66 mol) diluted to 750 ml with CH_2Cl_2 under the same conditions as described for **11**. After the addition was complete (7 h), the mixture was refluxed for additional 2 h. The residue obtained after evaporation was separated by FC (silica gel, AcOEt/petroleum ether 1:8): 58.98 g (45%) of *syn*-**21** (R_f 0.24) and 68.15 g (52%) of *anti*-**21** (R_f 0.27).

Data of syn-**21**: Colorless solid. M.p. 47.5–49.5°. $[\alpha]_D^{23} = -6.2$ (*c* = 0.78, $CHCl_3$). IR ($CHCl_3$): 1723. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.14 (*q*, *J* = 7.14, $MeCH_2O$); 3.97–3.86 (*m*, 4 H, OCH_2CH_2O); 2.53 (*m*, H−C(1′)); 2.43 (*m*,H−C(5′)); 1.83 (*dd*, *J* = 12.90, 4.05, 1 H−C(7′)); 1.61 (*dd*, *J* = 12.90, 3.84, 1 H−C(7′)); 1.57 (*dd*, *J* = 7.96, 7.96, H−C(3′)); 1.48 (*ddm*, *J* = 7.96, 6.72, H−C(4′)); 1.30 (*ddm*, *J* = 7.96, 6.72, H−C(2′)); 1.27 (*t*, *J* = 7.14, $MeCH_2O$); 1.20 (*dm*, *J* = 12.35, 1 H−C(8′)); 0.81 (*dm*, *J* = 12.35, 1 H−C(8′)). NOE: 2.53 (8.03, 1.83), 1.61 (16.15, 1.83), 1.48 (2.08, 1.57), 1.30 (5.04, 1.57), 2.43 (3.63, 1.48), 1.57 (4.34, 1.48), 1.30 (4.35, 1.48), 1.57 (5.50, 1.30), 1.48 (4.48, 1.30), 2.53 (0.65, 1.20), 2.43 (0.97, 1.20), 0.81 (12.41, 1.20), 2.53 (2.57, 0.81), 2.43 (3.93, 0.81), 1.20 (25.47, 0.81). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 172.17 (CO); 117.17 (C(6′)); 64.59, 64.01 (OCH_2CH_2O); 60.69 (CH_2O); 43.51 (C(7′)); 43.04 (C(5′)); 35.47 (C(1′)); 28.16 (C(8′)); 23.82 (C(3′)); 22.19 (C(2′)); 16.65 (C(4′)); 14.03 (Me). CI-MS (CH_4): 267 (7, $[M+29]^+$), 239 (52, $[M+1]^+$), 238 (6, M^+), 193 (100), 177 (7), 165 (6), 149 (10), 131 (1), 121 (4), 105 (3), 73 (7). Anal. calc. for $C_{13}H_{18}O_4$: C 65.53, H 7.61; found: C 65.70, 7.66.

Data of anti-**21**: Colorless oil. $[\alpha]_D^{22} = +54.6$ (*c* = 0.80, $CHCl_3$). IR ($CHCl_3$): 1719. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.10 (*q*, *J* = 7.12, $MeCH_2O$); 3.98–3.83 (*m*, OCH_2CH_2O); 2.39 (*m*, H−C(1′)); 2.29 (*m*, H−C(5′)); 1.78 (*dd*, *J* = 12.79, 4.00, H−C(7′)); 1.77 (*dd*, *J* = 2.58, 2.58, H−C(3′)); 1.70 (*dm*, *J* = 7.26, H−C(4′)); 1.65 (*dd*, *J* = 12.79, 3.71, 1 H−C(7′)); 1.54 (*dm*, *J* = 7.26, H−C(2′)); 1.24 (*t*, *J* = 7.12, $MeCH_2O$); 1.15 (*dm*, *J* = 11.33, 1 H−C(8′)); 0.98 (*dm*, *J* = 11.33, 1 H−C(8′)). NOE: 1.78 (5.13, 2.39), 1.54 (3.54, 2.39), 1.70 (4.41, 2.29), 2.39 (4.47, 1.78), 1.65 (18.89, 1.78), 2.29 (3.04, 1.70), 1.54 (3.44, 1.70), 2.39 (2.36, 1.65), 2.39 (3.18, 1.54), 2.39 (3.24, 1.15), 2.29 (3.21, 1.15), 0.97 (28.24, 1.15), 2.39 (2.64, 0.98), 1.77 (23.51, 0.98), 1.15 (25.71, 0.98). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 173.12 (CO); 116.89 (C(6)); 64.63, 64.00 (OCH_2CH_2O); 60.30 (CH_2O); 43.00 (C(5′)); 42.79 (C(7′)); 35.14 (C(1′)); 27.42 (C(8′)); 25.75 (C(2′)); 20.69 (C(4′)); 18.80 (C(3′)); 14.29 (Me). CI-MS (CH_4): 267 (8, $[M+29]^+$), 239 (69, $[M+1]^+$), 238 (14, M^+), 193 (100), 165 (6), 149 (6), 112 (5), 99 (7), 87 (27), 73 (18). Anal. calc. for $C_{13}H_{18}O_4$: C 65.53, H 7.61; found: C 65.68, H 7.76.

*(1′*R,*2′*R,*3′*R,*4′*S,*5′*R*)-Spiro[1,3-dioxolane-2,6′-tricyclo[3.2.1.0^{2,4}]octane]-3′-methanol* (*syn*-**25a**). A soln. of *syn*-**21** (54.8 g, 0.23 mol) in dry Et_2O (200 ml) was added dropwise over 2 h to an ice-cooled suspension of $LiAlH_4$ (8.73 g, 0.23 mol) in dry Et_2O (600 ml), and the mixture was stirred at r.t. for 24 h. Thereafter, the excess $LiAlH_4$ was decomposed by very slow addition of H_2O before the soln. was filtered. The aq. layer was extracted

with AcOEt (4×100 ml), the combined org. extract washed with brine (2×100 ml), dried (Na_2SO_4); and evaporated, and the residue purified by CC (AcOEt/CH_2Cl_2 1:1): 41.98 g (93%) of *syn*-**25a** (R_f 0.39). Colorless oil. $[\alpha]_D^{24} = +16.5$ ($c = 0.71$, $CHCl_3$). ^{1}H-NMR (360 MHz, $CDCl_3$): 3.97–3.85 (*m*, OCH_2CH_2O, CH_2OH); 2.43 (*m*, H–C(1′)); 2.35 (*m*, H–C(5′)); 1.82 (*dd*, $J = 12.55$, 4.00, 1 H–C(7′)); 1.61 (*dd*, $J = 12.55$, 3.71, 1 H–C(7′)); 1.43 (br. *s*, OH); 1.25 (*ddm*, $J = 7.70$, 7.42, H–C(3′)); 1.20 (*dm*, $J = 11.69$, 1 H–C(8′)); 1.11–1.04 (*m*, H–C(2′), H–C(4′)); 0.98 (*dm*, $J = 11.69$, 1 H–C(8′)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 117.50 (C(6′)); 64.42, 63.78 (OCH_2CH_2O); 60.63 (CH_2OH); 43.83 (C(7′)); 43.13 (C(5′)); 35.44 (C(1′)); 29.22 (C(8′)); 25.01 (C(3′)); 22.20 (C(2′)); 16.08 (C(4′)). CI-MS (CH_4): 198 (5, $[M+2]^+$), 197 (40, $[M+1]^+$), 196 (1, M^+), 195 (5, $[M-1]^+$), 180 (11), 179 (100), 153 (4), 135 (2), 118 (1), 117 (12), 99 (2), 87 (20), 86 (12), 73 (7). Anal. calc. for $C_{11}H_{16}O_3$: C 67.32, H 8.22; found: C 67.09, H 8.14.

*(1′*R*,2′*R*,3′*S*,4′*R*,5′*R*)-Spiro[1,3-dioxolane-2,6′-tricyclo[3.2.1.0^{2,4}]octane]-3′-methanol* (*anti*-**25a**). As described for *syn*-**25a**, with *anti*-**21** (59.6 g, 0.25 mol): *anti*-**25a** (46.12 g, 94%). Colorless oil. R_f 0.33: $[\alpha]_D^{24} = +31.1$ ($c = 0.37$, $CHCl_3$). ^{1}H-NMR (500.13 MHz, $CDCl_3$): 3.97–3.85 (*m*, OCH_2CH_2O); 3.43 (*dd*, $J = 11.00$, 7.05, 1 H, CH_2OH); 3.39 (*dd*, $J = 11.00$, 7.15, 1 H, CH_2OH); 2.33 (*m*, H–C(1′)); 2.24 (*m*, H–C(5′)); 1.77 (*dd*, $J = 12.80$, 4.05, 1 H–C(7′)); 1.58 (*dd*, $J = 12.80$, 3.65, 1 H–C(7′)); 1.45 (br. *s*, OH); 1.33 (*m*, H–C(3′)); 1.11 (*dm*, $J = 11.10$, 1 H–C(8′)); 1.03 (*dm*, $J = 11.10$, 1 H–C(8′)); 0.99 (*dm*, $J = 7.15$, H–C(4′)); 0.83 (*dm*, $J = 7.15$, H–C(2′)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 117.08 (C(6′)); 64.78, 64.30 (OCH_2CH_2O); 63.72 (CH_2OH); 43.26 (C(7′)); 42.73 (C(5′)); 34.86 (C(1′)); 27.28 (C(8′)); 20.99 (C(3′)); 19.02 (C(2′)); 15.20 (C(4′)). CI-MS (CH_4): 198 (4, $[M+2]^+$), 197 (35, $[M+1]^+$), 196 (1, M^+), 195 (7, $[M-1]^+$), 180 (11), 179 (100), 153 (4), 135 (4), 117 (14), 99 (2), 87 (14). Anal. calc. for $C_{11}H_{16}O_3$: C 67.32, H 8.22; found: C 67.06, H 8.49.

S-*Methyl* O-*[(1′*R*,2′*R*,3′*R*,4′*R*,5′*R*)-Spiro[1,3-dioxolane-2,6′-tricyclo[3.2.1.0^{2,4}]octane]-3′-yl] Carbonodithioate* (*syn*-**25b**). To a soln. of *syn*-**25a** (42.00 g, 0.214 mol) and DBN (53.16 g, 0.43 mol) in dry MeCN (150 ml), CS_2 (40 ml) was added, and the mixture was stirred for 2 h at r.t. Thereafter, MeI (78 ml) was added, and stirring was continued for a further 3 h at r.t. before the excess reactants and most of the solvent were evaporated to yield an oily residue, which was poured into H_2O (200 ml) and extracted with AcOEt (4×150 ml). The combined org. extract was washed with brine (100 ml), dried (Na_2SO_4), and evaporated and the residue purified by CC (AcOEt/petroleum ether 1:8): 58.84 g (96%) of *syn*-**25b** (R_f 0.5). Yellow oil. $[\alpha]_D^{25} = +1.4$ ($c = 0.84$, $CHCl_3$). IR ($CHCl_3$): 1198*s*, 1080*vs*, 1065*s*. ^{1}H-NMR (200 MHz, $CDCl_3$): 4.84 (*d*, $J = 5.86$, CH_2O); 3.98–3.85 (*m*, OCH_2CH_2O); 2.57 (*s*, MeS); 2.48 (*m*, H–C(1′)); 2.36 (*m*, H–C(5′)); 1.83 (*dd*, $J = 12.47$, 3.99, 1 H–C(7′)); 1.60 (*dd*, $J = 12.47$, 3.71, 1 H–C(7′)); 1.40–1.08 (*m*, H–C(2′), H–C(3′), H–C(4′), 1 H–C(8′)); 0.88 (*dm*, $J = 11.91$, 1 H–C(8′)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 215.24 (CS); 117.11 (C(6′)); 72.45 (CH_2O); 64.33, 63.72 (OCH_2CH_2O); 43.59 (C(7′)); 42.89 (C(5′)); 35.18 (C(1′)); 29.10 (C(8′)); 22.44 (MeS); 20.14 (C(2′)); 18.74 (C(3′)); 16.58 (C(4′)). CI-MS (CH_4): 288 (2, $[M+2]^+$), 287 (15, $[M+1]^+$), 285 (2, $[M-1]^+$), 243 (4), 239 (4), 211 (2), 181 (3), 180 (21), 179 (100), 167 (1), 135 (5), 119 (6), 118 (4), 118 (34), 99 (7), 93 (8), 91 (7), 87 (12), 73 (8), 41 (8). Anal. calc. for $C_{13}H_{18}O_3S_2$: C 54.52, H 6.33, S 22.39; found: C 54.72, H 6.48, S 22.51.

S-*Methyl* O-*[(1′*R*,2′*R*,3′*S*,4′*R*,5′*R*)-Spiro[1,3-dioxolane-2,6′-tricyclo[3.2.1.0^{2,4}]octane]-3′-yl] Carbonodithioate* (*anti*-**25b**): As described for *syn*-**25b**, with *anti*-**25a** (46.12 g, 0.235 mol): *anti*-**25b** (64.61 g, 96%). Slightly yellow oil. R_f 0.5. $[\alpha]_D^{25} = +26.6$ ($c = 0.73$, $CHCl_3$). IR ($CHCl_3$): 1196*m*, 1098*m*, 1063*s*. ^{1}H-NMR (200 MHz, $CDCl_3$): 4.43 (*dd*, $J = 11.29$, 7.42, 1 H, CH_2O); 4.36 (*dd*, $J = 11.29$, 7.42, 1 H, CH_2O); 3.99–3.81 (*m*, OCH_2-CH_2O); 2.57 (*s*, MeS); 2.37 (*m*, H–C(1′)); 2.27 (*m*, H–C(5′)); 1.78 (*dd*, $J = 12.77$, 4.00, 1 H–C(7′)); 1.60 (*dd*, $J = 12.77$, 3.22, 1 H–C(7′)); 1.57–1.45 (*m*, 1 H); 1.19–0.94 (*m*, 4 H). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 216.09 (CS); 117.09 (C(6′)); 76.36 (CH_2O); 64.56, 63.99 (OCH_2CH_2O); 43.31 (C(7′)); 42.90 (C(5′)); 35.01 (C(1′)); 27.34 (C(8′)); 21.68 (C(2′)); 19.06 (MeS); 16.13 (C(3′)); 14.92 (C(4′)). CI-MS (CH_4): 288 (2, $[M+2]^+$), 287 (11, $[M+1]^+$), 286 (2, M^+), 285 (2, $[M-1]^+$), 271 (1), 239 (2), 211 (1), 180 (18), 179 (100), 135 (1), 119 (2), 117 (11), 99 (3), 91 (1), 87 (3). Anal. calc. for $C_{13}H_{18}O_3S_2$: C 54.52, H 6.33, S 22.39; found: C 54.74, H 6.23, S 22.38.

*(1*RS*,2*RS*,3*RS*,4*RS*,5*RS*)-3-(Hydroxymethyl)tricyclo[3.2.1.0^{2,4}]octan-6-one* (*rac-syn*-**26a**). A soln. of *rac-syn*-**25a** (2.94 g, 15 mmol) in AcOH/H_2O 3:7 (20 ml) was stirred for 1 d at r.t. The mixture was then carefully neutralized adding dropwise 10% aq. NaOH soln., and the aq. phase was extracted with AcOEt (4×100 ml). The combined extracts were washed with brine (2×50 ml), dried (Na_2SO_4), and evaporated and the residue purified by FC (AcOEt/CH_2Cl_2 1:1): *rac-syn*-**26a** (2.15 g, 94%). Colorless oil. IR ($CHCl_3$): 1740. ^{1}H-NMR (200 MHz, $CDCl_3$): 3.98–3.92 (*m*, CH_2OH); 2.81–2.73 (*m*, 2 H–C(1), H–C(5)); 2.14–1.91 (*m*, 2 H–C(7)); 1.80 (br. *s*, OH); 1.37–1.22 (*m*, 2 H–C(8), H–C(3), H–C(4)); 1.12 (*dm*, $J = 7.08$, H–C(2)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 213.93 (C(6)); 59.33 (CH_2OH); 48.03 (C(5)); 44.25 (C(7)); 34.36 (C(1)); 28.30 (C(8)); 27.28 (C(3)); 23.24 (C(2)); 15.10 (C(4)). CI-MS (CH_4): 193 (4, $[M+41]^+$), 181 (9, $[M+29]^+$), 154 (9, $[M+2]^+$), 153 (100, $[M+1]^+$), 135 (31), 117 (14), 109 (25), 107 (47), 95 (10), 93 (39), 79 (21), 61 (14), 55 (7), 43 (7), 41 (35).

*(1*RS,*2*RS,*3*SR,*4*RS,*5*RS*)-3-(Hydroxymethyl)tricyclo[3.2.1.0^{2,4}]octan-6-one* (*rac-anti-***26a**). As described for *rac-syn-***26a**, with *rac-anti-***25a** (2.36 g, 12 mmol); *rac-anti-***26a** (1.74 g, 95%). Colorless oil. IR ($CHCl_3$): 1742. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 3.48 (*dd*, *J* = 11.28, 6.92, 1 H, C*H*$_2$OH); 3.45 (*dd*, *J* = 11.28, 6.92, 1 H, C*H*$_2$OH); 2.66 (*m*, H–C(1)); 2.64 (*m*, H–C(5)); 2.03 (*dd*, *J* = 16.78, 3.54, 1 H–C(7)); 1.97 (*dd*, *J* = 16.78, 4.23, 1 H–C(7)); 1.85 (*m*, CH$_2$O*H*); 1.66 (*m*, H–C(3)); 1.34 (*dm*, *J* = 11.60, H–C(8)); 1.17 (*dm*, *J* = 11.60, 1 H–C(8)); 1.10 (*dm*, *J* = 6.95, H–C(4)); 0.89 (*dm*, *J* = 6.95, H–C(2)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 214.24 (C(6)); 64.14 (CH_2OH); 48.07 (C(5)); 44.32 (C(7)); 34.43 (C(1)); 26.80 (C(8)); 22.15 (C(3)); 20.77 (C(2)); 14.87 (C(4)). CI-MS (CH_4): 193 (3, $[M+41]^+$), 181 (6, $[M+29]^+$), 154 (10, $[M+2]^+$), 153 (100, $[M+1]^+$), 152 (9, M^+), 135 (66), 117 (17), 107 (56), 79 (15), 55 (2).

S-*Methyl* O-*[(1*RS,*2*RS,*3*RS,*4*RS,*5*RS*)-6-Oxotricyclo[3.2.1.0^{2,4}]oct-3-yl] Carbonodithioate* (*rac-syn-***26b**). To a soln. of *rac-syn-***26a** (883 mg, 5.80 mmol) and DBN (1.44 g, 11.6 mmol) in dry MeCN (20 ml), CS_2 (3 ml) was added, and the mixture was stirred for 1 h at r.t. After addition of MeI (7 ml), stirring was continued for a further 90 min at r.t. The solvent was evaporated, the residue diluted with H_2O (25 ml) and extracted with AcOEt (4 × 25 ml), the combined org. extract washed with brine (25 ml), dried (Na_2SO_4), and evaporated, and the residue purified by CC (AcOEt/petroleum ether 1:8): *rac-syn-***26b** (1.27 mg, 90%). Yellow oil. ^{1}H-NMR (200 MHz, $CDCl_3$): 4.93 (*dd*, *J* = 11.57, 6.25, 1 H, CH_2O); 4.85 (*dd*, *J* = 11.57, 5.91, 1 H, CH_2O); 2.84–2.76 (*m*, H–C(1), H–C(5)); 2.58 (*s*, MeS); 2.08–1.98 (*m*, 2 H–C(7)); 1.62–1.14 (*m*, H–C(2), H–C(3), H–C(4), 2 H–C(8)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 215.67, 213.05 (CO, CS); 71.61 (CH_2O); 48.40 (C(5)); 44.58 (C(7)); 34.90 (C(1)); 28.88 (C(8)); 24.12 (C(2)); 23.27 (C(3)); 19.05 (MeS); 16.29 (C(4)). CI-MS (CH_4): 271 (3, $[M+29]^+$), 263 (11), 245 (10, $[M+3]^+$), 244 (11, $[M+2]^+$), 243 (100, $[M+1]^+$), 215 (9), 195 (23), 167 (35), 153 (6), 151 (3), 136 (8), 135 (60), 117 (27), 107 (61), 93 (40), 91 (21), 79 (24), 75 (9), 41 (42).

S-*Methyl* O-*[(1*RS,*2*RS,*3*SR,*4*RS,*5*RS*)-3-Oxotricyclo[3.2.1.0^{2,4}]oct-3-yl] Carbonodithioate* (*rac-anti-***26b**). As described for *rac-syn-***26b**, with *rac-anti-***26b**, (535 mg, 3.51 mmol): *rac-anti-***26b** (762 mg, 90%). Yellow solid. M.p. 73–75°. IR ($CHCl_3$): 1746. ^{1}H-NMR (200 MHz, $CDCl_3$): 4.41 (*d*, *J* = 7.22, CH_2O); 2.69–2.63 (*m*, H–C(1), H–C(5)); 2.55 (*s*, MeS); 2.04–1.93 (*m*, 2 H–C(7)); 1.82 (*m*, H–C(3)); 1.39–0.97 (*m*, H–C(2), H–C(3), 2 H–C(8)). ^{1}H-NMR (50.3 MHz, $CDCl_3$): 215.95, 213.40 (CO, CS); 74.77 (CH_2O); 47.93 (C(5)); 44.01 (C(7)); 34.35 (C(1)); 26.60 (C(8)); 22.53 (C(2)); 19.08 (MeS); 16.53 (C(3)); 15.43 (C(4)). CI-MS (CH_4): 271 (4, $[M+29]^+$), 263 (18), 245 (11, $[M+3]^+$), 244 (19), 243 (100, $[M+1]^+$), 214 (6), 195 (12), 167 (7), 151 (4), 136 (14), 135 (98), 117 (42), 107 (70), 93 (66), 91 (24), 79 (16), 75 (7), 55 (8), 41 (35).

*(1*RS,*4*RS,*6*RS*)-6-Ethenylbicyclo[2.2.1]heptan-2-one* (*rac-***27a**) *and (1*RS,*4*RS,*5*RS*)-5-Ethenylbicyclo[2.2.1]heptan-2-one* (*rac-***27b**). To a soln. of *rac-syn* or *rac-anti-***26b** (651 mg, 2.69 mmol) in toluene (30 ml), Bu_3SnH (1.07 ml, 4.04 mmol) and AIBN (89 mg, 0.54 mmol) were added. The soln. was purged of air by bubbling N_2 for 2 h and thereafter heated at 100° (oil-bath temp.) for 5 h. After evaporation, the residue was purified by CC (silica gel (230–430 mesh), AcOEt/petroleum ether 1:16): *rac-***27a**/*rac-***27b** 1:0.72 (by ^{1}H-NMR; 322 mg, 88%). Colorless oil. The isomers were separated by CC (*Merck* silica gel *60* (0.015–0.040 mm), AcOEt/petroleum ether 1:32).

Data of rac-**27a** (first eluted): IR ($CHCl_3$): 1740. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 5.78 (*ddd*, *J* = 17.14, 10.53, 6.54, CH_2=C*H*); 5.18 (*dm*, *J* = 17.14, 1 H, C*H*$_2$=CH); 5.13 (*dm*, *J* = 10.53, 1 H, C*H*$_2$=CH); 2.62 (*dm*, *J* = 6.54, H–C(6)); 2.55–2.52 (*m*, H–C(1), H–C(4)); 2.18 (*dm*, *J* = 17.90, 1 H); 2.02–1.85 (*m*, 3 H); 1.51 (*m*, 1 H); 1.43 (*m*, 1 H). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 216.55 (C(2)); 134.67 (Ch_2=*C*H); 117.04 (*C*H$_2$=CH); 53.82 (C(1)); 51.28 (C(6)); 46.64 (C(3)); 39.46 (C(4)); 24.98, 21.52 (C(5), C(7)). CI-MS (CH_4): 177 (4, $[M+41]^+$), 165 (10, $[M+29]^+$), 138 (10, $[M+2]^+$), 137 (100, $[M+1]^+$), 136 (3, M^+), 135 (1, $[M-1]^+$), 123 (3), 119 (20), 109 (21), 108 (4), 107 (2), 95 (13), 94 (4), 93 (14), 91 (5), 79 (4), 67 (8), 55 (2).

Data of rac-**27b**: IR ($CHCl_3$): 1734. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 5.85 (*ddd*, *J* = 17.27, 10.18, 7.22, CH_2=C*H*); 5.05–4.99 (*m*, C*H*$_2$=CH); 2.61 (*m*, H–C(5)); 2.51 (*m*, H–C(4)); 2.38 (*m*, H–C(1)); 2.11 (*dd*, *J* = 17.80, 4.60, 1 H–C(3)); 1.91 (*dd*, *J* = 17.80, 4.25 Hz, 1 H–C(3)); 1.81 (*ddd*, *J* = 13.28, 8.54, 2.20, 1 H–C(6)); 1.74 (*dm*, *J* = 10.70, 1 H–C(7)); 1.68–1.61 (*m*, 1 H–C(6), 1 H–C(7)). NOE: 2.11 (4.12, 2.51), 1.90 (1.53, 2.51), 2.38 (6.44, 1.81). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 217.20 (C(2)); 142.00 (CH_2=*C*H); 113.41 (*C*H$_2$=CH); 50.04 (C(5)); 45.09 (C(3)); 43.45 (C(1)); 40.94 (C(4)); 34.68, 30.89 (C(6), C(7)). CI-MS (CH_4): 177 (6, $[M+41]^+$), 165 (6, $[M+29]^+$), 138 (11, $[M+2]^+$), 137 (100, $[M+1]^+$), 136 (33, M^+), 135 (1, $[M-1]^+$), 119 (20), 118 (7), 109 (16), 108 (8), 107 (4), 95 (8), 94 (8), 93 (15), 92 (26), 91 (10), 79 (5), 67 (5).

*(1*R,*4*R*)-6-Ethenylspiro[bicyclo[2.2.1]heptane-2,2′-[1,3]dioxolane]* (**28a**) *and (1*R,*4*R,*5*R*)-5-Ethenylspiro-[bicyclo[2.2.1]heptane-2,2′-[1,3]dioxolane]* (**28b**). As described for *rac-***27a**/**b**, with *syn-* or *anti-***25b** (64.61 g, 0.226 mol), dry toluene (1.5 l), Bu_3SnH (120 ml, 0.452 mol), and AIBN (1.86 g, 11.3 mmol) (8 h at 120°): 39.11 g (96%) **28a**/**28b** 1:3.2, which were separated as described above. Further purification was achieved by CC (*Merck* silica gel *60* (0.015–0.040 mm), AcOEt/hexane 1:32).

Data of **28a** (first eluted): Colorless oil. $[\alpha]_D^{23} = -2.54$ ($c = 0.63$, $CHCl_3$). ^{1}H-NMR (500.13 MHz, $CDCl_3$): 5.76 (*ddd*, *J* = 17.26, 10.02, 7.41, CH_2=C*H*); 4.98 (*dm*, *J* = 17.26, 1 H, C*H*$_2$=CH); 4.90 (*dm*, *J* = 10.02, 1 H, C*H*$_2$=CH); 3.96–3.83 (*m*, OC*H*$_2$C*H*$_2$O); 2.70 (*m*, 1 H–C(6)); 2.29 (*m*, H–C(4)); 2.01 (*m*, H–C(1)); 1.81 (*ddd*, *J* = 13.13, 4.55, 3.03, 1 H–C(3)); 1.60 (*ddd*, *J* = 11.96, 8.93, 2.70, 1 H–C(5)); 1.55 (*dm*, *J* = 10.11, 1 H–C(7)); 1.46 (*dd*, *J* = 13.13, 3.37, 1 H–C(3)); 1.41 (*dm*, *J* = 10.11, 1 H–C(7)); 1.36 (*dm*, *J* = 11.96, 1 H–C(5)). NOE: 2.01 (2.92, 2.70), 1.60 (3.34, 2.70), 1.81 (3.79, 2.29), 1.60–1.36 (9.20, 2.29), 3.96–3.83 (4.44, 2.01), 2.70 (3.40, 2.01), 1.55 (1.76, 2.01), 1.41 (2.07, 2.01), 2.29 (4.54, 1.81), 1.46 (17.55, 1.81), 2.70 (11.12, 1.60), 2.29 (2.37, 1.60), 1.36 (24.65, 1.60), 2.29 (3.55, 1.55), 2.01 (4.29, 1.55), 1.41 (15.31, 1.55), 2.29 (2.26, 1.46), 1.80 (17.68, 1.46), 2.70 (1.54, 1.36), 2.29 (4.64, 1.36), 1.60 (19.53, 1.36). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 142.99 (CH_2=*C*H); 116.02 (*C*H_2=CH); 112.30 (C(2)); 64.48, 63.76 (O*C*H_2*C*H_2O); 49.49 (C(1)); 43.11 (C(3)); 38.62, 35.96 (C(4), C(6)); 35.90, 34.93 (C(5), C(7)). CI-MS (CH_4): 209 (3, $[M+29]^+$), 182 (11, $[M+2]^+$), 181 (100, $[M+1]^+$), 180 (45, M^+), 179 (18, $[M-1]^+$), 165 (1), 153 (2), 152 (2), 151 (3), 137 (5), 126 (7), 125 (4), 113 (4), 112 (4), 99 (7), 93 (7), 92 (11), 87 (4), 73 (8). HR-EI-MS (pos.): 180.1149 ($C_{11}H_{16}O_2^+$; calc. 180.1145).

Data of **28b**: Colorless oil. $[\alpha]_D^{24} = +49.9$ ($c = 1.33$, $CHCl_3$). ^{1}H-NMR (500.13 MHz, $CDCl_3$): 5.77 (*ddd*, *J* = 17.33, 10.13, 7.35, CH_2=C*H*); 4.95 (*dm*, *J* = 17.33, 1 H, C*H*$_2$=CH); 4.89 (*dm*, *J* = 10.13, 1 H, CH_2=CH); 3.95–3.81 (*m*, OC*H*$_2$C*H*$_2$O); 2.22 (*m*, H–C(5)); 2.15 (*m*, H–C(1)); 2.11 (*m*, H–C(4)); 1.97 (*ddd*, *J* = 12.80, 8.59, 2.27, 1 H–C(6)); 1.85 (*dd*, *J* = 13.31, 4.89, 1 H–C(3)); 1.54 (*dm*, *J* = 10.19, 1 H–C(7)); 1.50 (*dd*, *J* = 13.31, 3.40, 1 H–C(3)); 1.43 (*dm*, *J* = 10.19, 1 H–C(7)); 1.22 (*ddd*, *J* = 12.80, 4.57, 4.55, 1 H–C(6)). NOE: 1.97 (3.11, 2.22), 2.22 (5.20, 1.97), 1.22 (16.05, 1.97), 2.15 (1.91, 1.54), 2.11 (1.59, 1.54), 1.43 (17.63, 1.54), 2.15 (3.59, 1.43), 2.11 (1.99, 1.43), 1.54 (14.40, 1.43), 2.22 (5.55, 1.22), 2.15 (7.70, 1.22), 1.97 (15.11, 1.22). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 143.57 (CH_2=*C*H); 116.02 (*C*H_2=CH); 112.20 (C(2)); 64.44, 63.82 (O*C*H_2*C*H_2O); 44.28, 44.17, 41.44 (C(1), C(4), C(5)); 43.85, 34.88, 29.57 (C(3), C(6), C(7)). CI-MS (CH_4): 209 (3, $[M+29]^+$), 183 (1, $[M+3]^+$); 182 (14, $[M+2]^+$), 181 (100, $[M+1]^+$), 180 (13, M^+), 179 (15, $[M-1]^+$), 165 (2), 153 (2), 137 (36), 126 (39), 125 (6), 112 (6), 109 (6), 99 (8), 91 (4), 87 (9), 73 (22), 55 (3), 45 (11), 41 (24). Anal. calc. for $C_{11}H_{16}O_2$: C 73.30, H 8.95; found: C 73.14, H 8.82.

*(1*R*,4*R*,5*R*)-Spiro[bicyclo[2.2.1]heptane-2,2′-[1,3]dioxolane]-5-ethanol* (**29**). To a soln. of **28b** (9.55 g, 53 mmol) in dry THF (100 ml), 0.5M 9-BBN · THF complex soln. (233 ml, *ca.* 116.6 mmol) was added dropwise at 0° under N_2. After the addition was complete (3 h), the mixture was stirred for 5 h at r.t. and then cooled to 9° before 3M aq. NaOH (180 ml) was added. The thus obtained trialkylborane was oxidized by slow dropwise addition of 30% H_2O_2 soln. (180 ml) at 0°. After stirring overnight at r.t., the mixture was extracted with AcOEt (4 × 200 ml), the combined extract washed with sat. $Na_2S_2O_3$ soln. (3 × 80 ml) and brine (2 × 80 ml), dried (Na_2SO_4), and evaporated, and the residue purified by CC (AcOEt/CH_2Cl_2 1:2): 10.19 g (97%) of **29** (R_f 0.39). Colorless oil. $[\alpha]_D^{23} = +36.3$ ($c = 0.54$, $CHCl_3$). ^{1}H-NMR (500.13 MHz, $CDCl_3$): 3.96–3.82 (*m*, OC*H*$_2$C*H*$_2$O); 3.67–3.63 (*m*, CH_2C*H*$_2$OH); 2.13 (*m*, H–C(1)); 2.03 (*m*, H–C(4)); 1.93 (*ddd*, *J* = 12.64, 8.09, 2.11, 1 H–C(6)); 1.84 (*dd*, *J* = 13.13, 4.80, 1 H–C(3)); 1.65–1.58 (*m*, 3 H); 1.55 (*dm*, *J* = 10.11, 1 H–C(7)); 1.47–1.43 (*m*, 2 H); 1.41 (*dm*, *J* = 10.19, 1 H–C(7)); 0.97 (*ddd*, *J* = 12.64, 4.38, 4.38, 1 H–C(6)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 115.98 (C(2)); 64.48, 63.86 (O*C*H_2*C*H_2O); 61.64 (CH_2*C*H_2OH); 44.32 (C(3)); 44.17 (C(1)); 40.53 (C(4)); 39.73 (*C*H_2CH$_2$OH); 37.14 (C(5)); 34.78, 30.41 (C(6), C(7)). CI-MS (CH_4): 239 (1, $[M+41]^+$), 227 (1, $[M+29]^+$), 200 (10, $[M+2]^+$), 199 (86, $[M+1]^+$), 198 (27, M^+), 197 (17, $[M-1]^+$), 183 (2), 182 (11), 181 (100), 167 (1), 153 (12), 137 (5), 126 (6), 119 (4), 99 (5), 87 (3), 73 (3). Anal. calc. for $C_{11}H_{18}O_3$: C 66.64, H 9.15; found: C 66.62, H 9.34.

*(1*R*,4*R*,5*R*)-5-(2-Hydroxyethyl)bicyclo[2.2.1]heptan-2-one* (**30**). As described for *rac-syn*-**26a**, with **29** (9.93 g, 50.1 mmol). Purification of the product (R_f 0.34) by CC (silica gel, AcOEt/CH_2Cl_2 1:2) yielded **30** 7.26 g (94%). Colorless oil. $[\alpha]_D^{23} = +53.2$ ($c = 0.44$, $CHCl_3$). IR ($CHCl_3$): 1740. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 3.74–3.65 (*m*, CH_2C*H*$_2$OH); 2.58 (*m*, H–C(1)); 2.44 (*m*, H–C(4)); 2.09 (*dd*, *J* = 17.69, 4.70, 1 H–C(3)); 1.85 (*dd*, *J* = 17.69, 2.96, 1 H–C(3)); 1.83–1.71 (*m*, 4 H); 1.70 (*m*, 1 H); 1.66 (*dm*, *J* = 10.61, 1 H–C(7)); 1.56 (*m*, 1 H); 1.38 (*dm*, *J* = 12.29, 2 H–C(6)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 217.88 (C(2)); 61.34 (CH_2*C*H_2OH); 50.19 (C(1)); 45.61 (C(4)); 39.99 (C(3)); 39.38 (*C*H_2CH$_2$OH); 36.74 (C(5)); 34.72, 31.82 (C(6), C(7)). CI-MS (CH_4): 195 (4, $[M+41]^+$), 183 (9, $[M+29]^+$), 156 (16, $[M+2]^+$), 155 (100, $[M+1]^+$), 154 (10, M^+), 137 (25), 119 (12), 111 (13), 110 (14), 109 (27), 108 (9), 107 (7), 93 (39), 79 (6), 67 (8), 55 (3). Anal. calc. for $C_9H_{14}O_2$: C 70.10, H 9.15; found: C 69.96, H 9.40.

*(1*R*,2*S*,4*R*)-Spiro[bicyclo[2.2.1]hept-5-ene-2,2′-oxirane]* (**18**). To a soln. of **17** [17] (185 g, 0.911 mol) in MeOH (480 ml), K_2CO_3 (252 g, 1.822 mol) was added at r.t. After 10 h stirring, ice-cold H_2O (960 ml) was added, and the mixture was extracted with Et_2O (4 × 200 ml). The combined extract was washed with brine (4 × 100 ml) and dried ($MgSO_4$), the solvent distilled off through a short *Vigreux* column, and the residue purified by CC (pentane/Et_2O 6:1): 102.4 g (92%) of **18** besides the 2-*O*-methyl ether corresponding to **19** (2.81 g, 2%).

Data of **18**: Colorless oil. R_f 0.76. $[\alpha]_D^{20} = +156$ ($c = 1.16$, $CHCl_3$). ^{1}H-NMR (500.13 MHz, $CDCl_3$): 6.32 (*dd*, *J* = 5.72, 2.92, H−C(5)); 6.09 (*dd*, *J* = 5.72, 3.20, H−C(6)); 2.95 (*m*, H−C(4)); 2.84 (*d*, *J* = 4.57, 1 H, CH_2O); 2.81 (*d*, *J* = 4.57, 1 H, CH_2O); 2.32 (*m*, H−C(1)); 1.92 (*dm*, *J* = 8.51, 1 H−C(7)); 1.77 (*dm*, *J* = 8.51, 1 H−C(7)); 1.69 (*dd*, *J* = 12.53, 3.48, 1 H−C(3)); 1.56 (*dd*, *J* = 12.53, 2.83, 1 H−C(3)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 140.47 (C(5)); 133.12 (C(6)); 66.30 (C(2)); 50.97 (CH_2O); 49.33 (C(7)); 48.91 (C(1)); 41.57 (C(4)); 33.97 (C(3)). CI-MS (CH_4): 151 (5, $[M+29]^+$), 137 (1, $[M+15]^+$), 124 (5, $[M+2]^+$), 123 (60, $[M+1]^+$), 122 (15, M^+), 121 (11, $[M-1]^+$), 113 (4), 105 (10), 95 (15), 91 (15), 85 (9), 81 (8), 80 (20), 79 (21), 67 (100), 66 (13), 57 (10).

*Data of (1*R,*2*S,*4*R*)-2-Methoxybicyclo[2.2.1]hept-5-ene-2-methanol:* Colorless oil. R_f 0.25. $[\alpha]_D^{22} = +21.6$ ($c = 3.25$, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$): 6.15 (*dd*, *J* = 5.72, 2.92, H−C(5)); 6.02 (*dd*, *J* = 5.72, 3.20, H−C(6)); 3.38 (*s*, MeO); 3.27 (*d*, *J* = 9.09, 1 H, CH_2OH); 3.21 (*d*, *J* = 9.09, 1 H, CH_2OH); 2.83 (*m*, H−C(4)); 2.69 (*m*, H−C(1)); 2.66 (*s*, OH); 1.92 (*dm*, *J* = 8.50, 1 H−C(7)); 1.62 (*dd*, *J* = 12.31, 3.72, 1 H−C(3)); 1.59 (*dm*, *J* = 8.50, 1 H−C(7)); 1.11 (*dd*, *J* = 12.31, 2.73, 1 H−C(3)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 138.98 (C(5)); 134.10 (C(6)); 80.99 (C(2)); 78.66 (CH_2OH); 59.19 (MeO); 51.25 (C(1)); 47.80 (C(7)); 41.25 (C(4)); 38.86 (C(3)). CI-MS (CH_4): 155 (2, $[M+1]^+$), 154 (16, M^+), 138 (3, $[(M+2)-18]^+$), 137 (29, $[(M+1)-18]^+$), 136 (1, $[M-18]^+$), 123 (3), 122 (5), 121 (2), 109 (5), 105 (4), 95 (7), 89 (2), 88 (3), 87 (3), 81 (4), 72 (5), 71 (100), 66 (11).

*(1*R,*2*S,*4*R*)-2-Hydroxybicyclo[2.2.1]hept-5-ene-2-methanol* (**19**). To a stirred soln. of **18** (102 g, 0.835 mol) in dioxane (700 ml), a soln. of KOH (281 g) in H_2O (700 ml) was added, and stirring was continued for 48 h at 105°. After cooling to r.t., the mixture was extracted by Et_2O, washed with brine, dried ($MgSO_4$), and evaporated and the residue purified by CC (AcOEt/Et_2O 1:1): 114.7 g (98%) of **19** besides 1.6 g (1.5%) of the corresponding [oxybis(methylene)]bis[bicyclo[2.2.1]heptene].

Data of **19**. R_f 0.54. White solid. M.p. 82–84° (hexane). $[\alpha]_D^{23} = +26$ ($c = 0.3$, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$): 6.17 (*dd*, *J* = 5.71, 2.92, H−C(5)); 6.06 (*dd*, *J* = 5.71, 3.13, H−C(6)); 3.50 (*d*, *J* = 11.00, 1 H, CH_2OH); 3.42 (*d*, *J* = 11.00, 1 H, CH_2OH); 2.87 (*m*, H−C(4)); 2.72 (*m*, H−C(1)); 2.24 (br., 2 OH); 1.92 (*dm*, *J* = 8.55, 1 H−C(7)); 1.63 (*dm*, *J* = 8.55, 1 H−C(7)); 1.62 (*dd*, *J* = 12.30, 3.72, 1 H−C(3)); 1.18 (*dd*, *J* = 12.30, 2.79, 1 H−C(3)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 139.06 (C(5)); 133.79 (C(6)); 82.33 (C(2)); 68.60 (CH_2OH); 50.59 (C(1)); 47.81 (C(7)); 41.37 (C(4)); 39.14 (C(3)). CI-MS (CH_4): 141 (2, $[M+1]^+$), 140 (6, M^+), 123 (44), 113 (3), 109 (6), 105 (3), 95 (12), 85 (11), 81 (6), 79 (7), 67 (100), 66 (14), 57 (10). Anal. calc. for $C_8H_{12}O_2$: C 68.55, H 8.63; found: C 68.32, H 8.74.

*Data of (1*R,*1′*R,*4*R,*4′*R,*5*S,*5′*S*)-5,5′-[Oxybis(methylene)]bis[bicyclo[2.2.1]hept-2-ene]:* R_f 0.78. White solid. M.p. 117–118° (hexane). $[\alpha]_D^{20} = +50.2$ ($c = 0.54$, $CHCl_3$). ^{1}H-NMR (200 MHz, $CDCl_3$): 6.16 (*dd*, *J* = 5.70, 2.94, H−C(2), H−C(2′)); 6.01 (*dd*, *J* = 5.70, 3.17, H−C(3), H−C(3′)); 3.37 (*d*, *J* = 9.33, 2 H, CH_2OCH_2); 3.19 (*d*, *J* = 9.33, 2 H, CH_2OCH_2); 2.85 (*m*, H−C(1), H−C(1′)); 2.71 (*m*, H−C(4), H−C(4′)); 2.67 (br., 2 OH); 1.94 (*dm*, *J* = 8.36, 2 H, H−C(7), H−C(7′)); 1.66 (*dm*, *J* = 8.55, 2 H, H−C(7), H−C(7′)); 1.65 (*dd*, *J* = 12.30, 3.71, 2 H, H−C(6), H−C(6′)); 1.12 (*dd*, *J* = 12.30, 2.66, 2 H, H−C(6), H−C(6′)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 139.16 (2 C, C(2), C(2′)); 133.96 (2 C, C(3), C(3′)); 81.27 (2 C, C(5), C(5′)); 77.43 (2 C, CH_2OCH_2); 51.31 (2 C, C(4), C(4′)); 47.78 (2 C, C(7), C(7′)); 41.25 (2 C, C(1), C(1′)); 38.82 (2 C, C(6), C(6′)). CI-MS (CH_4): 263 (2, $[M+1]^+$), 246 (7, $[(M+2)-18]^+$), 245 (34, $[(M+1)-18]^+$), 244 (22, $[M-18]^+$), 227 (7), 180 (11), 179 (100), 178 (29), 177 (9), 161 (19), 133 (6), 124 (6), 123 (57), 122 (13), 113 (17), 105 (18), 95 (11), 79 (8), 67 (13). Anal. calc. for $C_{16}H_{22}O_3$: C 73.25, H 8.45; found: C 73.25, H 8.64.

*(1*R,*4*R,*5*S*)-Spiro[bicyclo[2.2.1]heptane-2,2′-[1,3]dioxolane]-5-methanol* (**31**). Ozone was bubbled into a soln. of **28b** (9.91 g, 55 mmol) in CH_2Cl_2/MeOH 2:1 (300 ml) at −78° until a blue color persisted. Thereafter, the mixture was purged of ozone with N_2 until the soln. became colorless, and $NaBH_4$ (5.20 g, 137.5 mmol) was added. The mixture was allowed to warm to r.t. and then stirred for 2 h before most of the solvent was evaporated. Then, H_2O (100 ml) was added, the aq. layer extracted with AcOEt (5 × 100 ml), the combined extract washed with brine (2 × 50 ml), dried (Na_2SO_4), and evaporated, and the residue purified by CC (AcOEt/CH_2Cl_2 1:2): 9.71 g (96%) of **31**. R_f 0.36. Colorless oil. $[\alpha]_D^{23} = +17.2$ ($c = 0.46$, $CHCl_3$). ^{1}H-NMR (500.13 MHz, $CDCl_3$): 3.96–3.81 (*m*, OCH_2CH_2O); 3.44 (*dd*, *J* = 10.51, 6.23, 1 H, CH_2OH); 3.40 (*dd*, *J* = 10.51, 8.59, 1 H, CH_2OH); 2.24 (*m*, H−C(1)); 2.13 (*m*, H−C(4)); 1.89 (*dd*, *J* = 13.30, 4.88, H−C(3)); 1.86 (*ddd*, *J* = 12.43, 8.44, 2.26, 1 H−C(6)); 1.78 (*m*, H−C(5)); 1.65 (br. *s*, CH_2OH); 1.55 (*dm*, *J* = 10.44, 1 H−C(7)); 1.47 (*dd*, *J* = 13.30, 3.53, 1 H−C(3)); 1.36 (*dm*, *J* = 10.44, 1 H−C(7)); 0.91 (*ddd*, *J* = 12.43, 4.55, 4.55, 1 H−C(6)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 116.05 (C(2)); 66.59 (CH_2OH); 64.52, 63.88 (OCH_2CH_2O); 44.06 (C(3)); 43.77 (C(1)); 43.55 (C(4)); 37.47 (C(5)); 34.56, 26.44 (C(6), C(7)). CI-MS (CH_4): 186 (5, $[M+2]^+$), 185 (42, $[M+1]^+$), 184 (10, M^+), 183 (12, $[M-1]^+$), 168 (10), 167 (100), 153 (3), 141 (26), 123 (21), 113 (3), 105 (4), 99 (5), 95 (12), 79 (6), 73 (10), 67 (2), 55 (2). Anal. calc. for $C_{10}H_{16}O_3$: C 65.19, H 8.75; found: C 65.10, H 8.92.

*(1*R*,4*R*,5*S*)-5-(Hydroxymethyl)bicyclo[2.2.1]heptan-2-one* (**32**). A soln. of **31** (9.55 g, 51.83 mmol) in AcOH/H_2O 3:7 (100 ml) was stirred for 2 d at r.t. The mixture was then carefully neutralized by adding dropwise 10% aq. NaOH soln. and then extracted with AcOEt (5 × 150 ml). The combined extract was washed with brine (2 × 50 ml) and dried (Na_2SO_4) and the residue purified by FC (AcOEt/CH_2Cl_2 1:1): 6.78 g (93%) of **32**. R_f 0.33. Colorless oil. $[\alpha]_D^{23} = +25.3$ ($c = 0.85$, $CHCl_3$). IR ($CHCl_3$): 1742. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 3.56 (*dd*, *J* = 10.61, 6.40, 1 H, C*H*$_2$OH); 3.53 (*dd*, *J* = 10.61, 8.59, 1 H, C*H*$_2$OH); 2.65 (*m*, H–C(1)); 2.59 (*m*, H–C(4)); 2.14 (*dd*, *J* = 17.69, 4.72, 1 H–C(3)); 1.93 (*m*, H–C(5)); 1.89 (*dm*, *J* = 17.69, 1 H–C(3)); 1.71 (*dd*, *J* = 13.14, 8.59, 1 H–C(6)); 1.69–1.65 (*m*, 2 H–C(7), CH_2O*H*); 1.35 (*ddd*, *J* = 13.14, 4.88, 4.88, 1 H–C(6)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 217.60 (C(2)); 66.04 (CH_2OH); 49.77 (C(1)); 45.46 (C(3)); 42.90 (C(4)); 37.16 (C(5)); 34.59, 28.08 (C(6), C(7)). CI-MS (CH_4): 181 (2, $[M+41]^+$), 169 (5, $[M+29]^+$), 142 (8, $[M+2]^+$), 141 (100, $[M+1]^+$), 140 (8, M^+), 123 (26), 122 (4), 105 (5), 96 (3), 95 (24), 94 (3), 93 (6), 81 (7), 80 (3), 79 (15), 69 (1), 67 (4). Anal. calc. for $C_8H_{12}O_2$: C 68.55, H 8.63; found: C 68.23, H 8.93.

*(1*R*,5*R*,6*S*)-6-(Hydroxymethyl)-2-oxabicyclo[3.2.1]octan-3-one* (**33**). As described for **14**, procedure *b*), with **32** (6.64 g, 47.4 mmol), $NaHCO_3$ (7.97 g, 94.8 mmol), *ca.* 55% MCPBA (29.82 g, 94.8 mmol), and CH_2Cl_2 (650 ml): 6.29 g (85%) of **33**. R_f 0.34. Colorless oil. $[\alpha]_D^{23} = +13.7$ ($c = 1.02$, $CHCl_3$). IR ($CHCl_3$): 1726. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.87 (*m*, H–C(1)); 3.55 (*dd*, *J* = 10.52, 5.90, 1 H, C*H*$_2$OH); 3.44 (*dd*, *J* = 10.52, 8.16, 1 H, C*H*$_2$OH); 2.78 (*dd*, *J* = 18.53, 4.96, 1 H–C(4)); 2.56 (*ddd*, *J* = 18.53, 2.27, 1.94, 1 H–C(4)); 2.45 (*m*, H–C(5)); 2.35 (*ddd*, *J* = 14.90, 8.72, 2.61, 1 H–C(7)); 2.21 (*m*, H–C(6)); 1.92 (*dm*, *J* = 13.06, 1 H–C(8)); 1.80 (*dm*, *J* = 13.06, 1 H–C(8)); 1.89–1.72 (br., CH_2O*H*); 1.53 (*ddd*, *J* = 14.90, 5.31, 4.21, 1 H–C(7)). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 170.29 (C(3)); 81.15 (C(1)); 65.60 (CH_2OH); 44.90 (C(5)); 41.15 (C(4)); 36.27, 33.65 (C(7), C(8)); 34.05 (C(6)). CI-MS (CH_4): 158 (6, $[M+2]^+$), 157 (63, $[M+1]^+$), 140 (10), 139 (100), 121 (35), 111 (14), 97 (14), 95 (17), 94 (7), 93 (42), 81 (7), 79 (33), 67 (6), 61 (24). Anal. calc. for $C_8H_{12}O_3$: C 61.52, H 7.74; found: C 61.14, H 8.00.

*Methyl (1*R*,2*S*,4*R*)-4-Hydroxy-2-(hydroxymethyl)cyclopentaneacetate* (**34a**). As described for **15a**, with **33** (5.3 g, 34 mmol): **34a** (5.76 g, 90%). The crude product was used without further purification for the next step. IR ($CHCl_3$): 1726. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.32 (*m*, H–C(4)); 3.68 (*s*, MeO); 3.57 (*d*, *J* = 5.81, C*H*$_2$OH); 2.64 (*dd*, *J* = 16.15, 6.72, 1 H, CH_2COO); 2.47 (*dd*, *J* = 16.15, 6.71, 1 H, CH_2COO); 2.56–2.04 (*m*, 4 H); 1.83 (*dddd*, *J* = 13.47, 7.59, 3.15, 1.66, 1 H); 1.62 (*ddd*, *J* = 13.47, 9.08, 5.68, 1 H); 1.42 (*dddd*, *J* = 13.36, 6.56, 4.01, 1.65, 1 H). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 174.37 (CO); 72.49 (C(4)); 65.49 (CH_2OH), 51.62 (MeO); 45.59 (C(2)); 41.80 (*C*H_2CO_2Me); 39.95, 39.14 (C(3), C(5)); 36.65 (C(1)). CI-MS (CH_4): 217 (6, $[M+29]^+$), 190 (9, $[M+2]^+$), 189 (77, $[M+1]^+$), 172 (7), 171 (70), 154 (12), 153 (100), 139 (54), 121 (34), 111 (9), 93 (37), 79 (10), 75 (6), 61 (4).

*Methyl (1*R*,2*S*,4*R*)-{{[(*tert*-Butyl)diphenylsilyl]oxy}methyl}-4-hydroxycyclopentaneacetate* (**34b**). As described for **15b**, with **34a** (5.84 g, 31 mmol): **34b** (9.30 g, 70%). Colorless syrup. *R* (AcOEt/CH_2Cl_2 1:8) 0.35. $[\alpha]_D^{23} = +12.8$ ($c = 0.75$, $CHCl_3$). IR ($CHCl_3$): 1730. ^{1}H-NMR (360 MHz, $CDCl_3$): 7.68–7.61 (*m*, 4 arom. H); 7.46–7.34 (*m*, 6 arom. H); 4.31 (*m*, H–C(4)); 3.63 (*s*, MeO); 3.60 (*d*, *J* = 5.14, CH_2O); 2.60 (*dd*, *J* = 15.54, 4.42, 1 H, CH_2COO); 2.38 (*dd*, *J* = 15.54, 8.11, 1 H, CH_2COO; 2.30–2.08 (*m*, 3 H); 2.01 (br. *s*, OH); 1.83–1.75 (*m*, 1 H); 1.72–1.62 (*m*, 1 H); 1.44–1.36 (*m*, 1 H); 1.05 (*s*, ^{t}Bu). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 176.68 (CO); 135.61, 133.76, 129.61, 127.64 (12 arom. C); 72.80 (C(4)); 66.35 (CH_2O); 51.33 (MeO); 45.14 (C(2)); 41.87 (*C*H_2CO_2Me); 39.74, 39.10 (C(3), C(5)); 36.80 (C(1)); 26.88 (3 C, *Me*$_3$C); 19.26 (Me$_3$*C*). FAB-MS: 449 (13, $[M+Na]^+$), 427 (23, $[M+1]^+$), 409 (7), 369 (96), 343 (36), 331 (20), 239 (15), 213 (74), 199 (100), 183 (44), 153 (72), 135 (100), 121 (76). Anal. calc. for $C_{25}H_{34}O_4Si$: C 70.38, H 8.03; found: C 69.98, H 8.06.

*Methyl (1*R*,2*S*,4*R*)-{{[(*tert*-Butyl)diphenylsilyl]oxy}methyl}-4-[(methylsulfonyl)oxy]cyclopentaneacetate* (**35**). Methanesulfonyl chloride (1.77 g, 15.45 mmol) was added dropwise to a stirred, ice-cooled soln. of **34b** (5.07 g, 11.88 mmol) in CH_2Cl_2 (150 ml) containing DMAP (2.90 g, 23.76 mmol), and then the mixture was stirred for 30 min before it was diluted with CH_2Cl_2 (150 ml). Then, the soln. was washed successively with sat. aq. $NaHCO_3$ soln. (80 ml) and brine (80 ml), dried (Na_2SO_4), and evaporated and the residue purified by CC (AcOEt/petroleum ether 1:2): 5.92 g (99%) of **35**. R_f 0.79. Colorless syrup. $[\alpha]_D^{23} = +16.2$ ($c = 0.71$, $CHCl_3$). IR ($CHCl_3$): 1732. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 7.66–7.62 (*m*, 4 arom. H); 7.46–7.36 (*m*, 6 arom. H); 5.13 (*m*, H–C(4)); 3.63 (*s*, MeO); 3.64 (*dd*, *J* = 10.28, 4.90, 1 H, CH_2O); 3.59 (*dd*, *J* = 10.28, 5.06, 1 H, CH_2O); 2.99 (*s*, $MeSO_2$); 2.60–2.53 (*m*, 1 H); 2.43 (*ddd*, *J* = 14.39, 8.15, 5.96, 1 H); 2.33–2.22 (*m*, 2 H); 2.12 (*dddd*, *J* = 13.48, 7.60, 2.84, 1.70, 1 H); 2.09–2.02 (*m*, 1 H); 1.89 (*ddd*, *J* = 13.28, 8.80, 5.76, 1 H); 1.72 (*dddd*, *J* = 14.39, 6.93, 4.05, 1.60, 1 H); 1.05 (*s*, ^{t}Bu). ^{13}C-NMR (125.76 MHz, $CDCl_3$): 172.96 (CO); 135.55, 133.30, 129.73, 127.72 (12 arom. C); 83.33 (C(4)); 65.13 (CH_2O), 51.53 (MeO); 45.03 ($MeSO_2$); 39.57, 39.52 (C(3), C(5)); 38.43, 36.14 (C(1), C(2)); 36.57 (*C*H_2CO_2Me); 26.83 (3 C, *Me*$_3$C); 19.23 (Me$_3$*C*). FAB-MS: 527 (5, $[M+Na]^+$), 505 (4,

$[M+1]^+$), 473 (6), 447 (51), 427 (13), 409 (25), 377 (6), 351 (21), 331 (37), 277 (73), 257 (18), 239 (24), 213 (100), 183 (82), 153 (100), 121 (100). Anal. calc. for $C_{26}H_{36}O_6SSi$: C 61.87, H 7.19; found: C 61.83, H 7.02.

*Methyl (1*R*,2*S*,4*S*)-4-(6-Amino-9*H*-purin-9-yl)-2-{{[(*tert*-butyl)diphenylsilyl]oxy}methyl}cyclopentaneacetate* (**36**). Adenine (1.21 g, 8.93 mmol) and K_2CO_3 (1.65 g, 11.90 mmol) were added to a soln. of **35** (3.0 g, 5.95 mmol) in dry DMSO (30 ml), and the mixture was stirred at 85° for 1 d. After evaporation, the residue was dissolved in CH_2Cl_2 (1.2 l), the soln. washed successively with H_2O (3 × 100 ml) and brine (3 × 100 ml), dried (Na_2SO_4), and evaporated, and the residue purified by CC (CH_2Cl_2/EtOH 20 : 1): 1.86 g (58%) of **36**. R_f 0.22. White solid. M.p. 134–135° (from CH_2Cl_2/petroleum ether). $[\alpha]_D^{24} = +11.43$ ($c = 0.84$, $CHCl_3$). UV ($CHCl_3$): 262 (21600). IR (KBr): 1740, 1667, 1599. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 8.35 (*s*, H–C(2′)); 7.88 (*s*, H–C(8′)); 7.68–7.62 (*m*, 4 arom. H); 7.46–7.36 (*m*, 6 arom. H); 5.99 (*s*, NH_2); 4.99 (*m*, 1 H–C(4′)); 3.76 (*dd*, $J = 10.33$, 4.67, 1 H, CH_2O); 3.71 (*dd*, $J = 10.33$, 5.07, 1 H, CH_2O); 3.64 (*s*, MeO); 2.65–2.54 (*m*, 2 H); 2.51–2.45 (*m*, 1 H); 2.39–2.26 (*m*, 2 H); 2.10 (*m*, 1 H); 2.04–1.94 (*m*, 2 H); 1.07 (*s*, ^{t}Bu). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 172.80 (CO); 155.48 (C(6′)); 152.70 (C(2′)); 150.07 (C(4′)); 138.42 (C(8′)); 135.56, 133.31, 129.76, 127.72 (12 arom. C); 119.95 (C(5′)); 65.21 (CH_2O); 53.62 (C(4)); 51.59 (MeO); 46.29 (C(1)); 39.11, 38.47 (C(3), C(5)); 36.42 (*C*H_2CO_2Me); 36.09 (C(2)); 26.88 (3 C, *Me*$_3$*C*); 19.25 (Me$_3$*C*). FAB-MS: 546 (13, $[M+2]^+$), 545 (34, $[M+1]^+$), 544 (79, M^+), 486 (10), 466 (9), 288 (40), 255 (8), 213 (44), 197 (44), 183 (31), 136 (100), 121 (50). Anal. calc. for $C_{30}H_{37}N_5O_3Si$: C 66.27, H 6.86, N 12.88; found: C 66.17, H 7.00, N 12.85.

*Methyl (1*R*,2*S*,4*S*)-2-{{[(*tert*-Butyl)diphenylsilyl]oxy}methyl}-4-(1,2,3,4-tetrahydro-5-methyl-2,4-dioxopyrimidin-1-yl)cyclopentaneacetate* (**37**). A mixture of **35** (1.45 g, 2.87 mmol) and thymine (906 mg, 7.18 mmol) in dry DMF (20 ml) containing [18]crown-6 (1.14 g, 4.31 mmol) as phase-transfer catalyst, and K_2CO_3 (992 mg, 7.18 mmol) was stirred at 85° for 2 d. After dilution with AcOEt (1 l), the mixture was washed successively with H_2O (4 × 100 ml) and brine (100 ml), dried (Na_2SO_4), and evaporated and the residue purified by FC (AcOEt/CH_2Cl_2/EtOH 20 : 40 : 1): 599 mg (39%) of **37**. R_f 0.58. White frothy solid. M.p. 48–51°. $[\alpha]_D^{24} = -2.27$ ($c = 0.22$, $CHCl_3$). UV ($CHCl_3$): 272 (13100). IR (KBr): 1736, 1690. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 8.98 (*s*, H–N(3′)); 7.67–7.62 (*m*, 4 arom. H); 7.47–7.36 (*m*, 6 arom. H); 7.04 (*d*, $J = 1.12$, H–C(6′)); 5.05 (*m*, 1 H–C(4′)); 3.72 (*dd*, $J = 10.44$, 4.58, 1 H, CH_2O); 3.69 (*dd*, $J = 10.44$, 4.90, 1 H, CH_2O); 3.64 (*s*, MeO); 2.51 (*dd*, $J = 15.45$, 4.58, 1 H); 2.48–2.41 (*m*, 1 H); 2.25–2.20 (*m*, 1 H); 2.19 (*dd*, $J = 15.45$, 9.16, 1 H); 2.04–2.18 (*m*, 1 H); 1.91 (*d*, $J = 1.12$, Me–C(5′)); 1.90–1.80 (*m*, 2 H); 1.63 (*m*, 1 H); 1.07 (*s*, ^{t}Bu). ^{13}C-NMR (125.76 MHz, $CDCl_3$): 172.84 (CO); 163.56 (C(4′)); 151.08 (C(2′)); 136.29 (C(6′)); 135.53, 133.26, 129.79, 127.73 (12 arom. C); 111.27 (C(5′)); 64.65 (CH_2O); 53.62 (C(4)); 51.56 (MeO); 45.91 (C(1)); 38.92, 37.00, 36.13 (C(2)); 35.18, 26.88 (3 C, *Me*$_3$C); 19.24 (*Me*–C(5′)); 12.62 (Me$_3$*C*). FAB-MS: 559 (3, $[(M+1)+Na]^+$), 558 (11, $[M+Na]^+$), 557 (27, $[(M-1)+Na]^+$), 536 (10, $[M+1]^+$), 535 (26, M^+), 477 (35), 457 (16), 409 (5), 369 (4), 351 (15), 331 (14), 307 (20), 287 (10), 279 (34), 247 (18), 213 (85), 197 (10), 183 (53), 153 (66), 135 (100). HR-ESI-MS (MeOH/$CHCl_3$): 557.2432 ($C_{30}H_{38}N_2O_5SiNa^+$, $[M+Na]^+$; calc. 557.2442). Anal. calc. for $C_{30}H_{38}N_2O_5Si$: C 67.39, H 7.16, N 5.24; found: C 66.90, H 7.38, N 4.98.

*Ethyl (1*R*,2*R*,3*R*,4*S*,5*R*)-7-Oxo-6-oxatricyclo[3.3.1.0^{2,4}]nonane-3-carboxylate* (*syn*-**38**). As described for **14**, procedure *b*), with *syn*-**11** (4.94 g, 25.43 mmol), $NaHCO_3$ (4.27 g, 50.86 mmol), CH_2Cl_2, and MCPBA (15.96 g, 50.86 mmol) (20 h). Purification by CC (AcOEt/petroleum ether 1 : 1) yielded 5.19 g (97%) of *syn*-**38**. Colorless solid. M.p. 85–87°. $[\alpha]_D^{22} = +67.1$ ($c = 0.83$, $CHCl_3$). IR (KBr): 1726. ^{1}H-NMR (360 MHz, $CDCl_3$): 4.87 (*m*, H–C(5)); 4.14 (*dq*, $J = 7.13$, 2.18, MeC*H*$_2$O); 2.79 (*dd*, $J = 18.34$, 4.66, H–C(8)); 2.71–2.64 (*m*, 1 H–C(8), H–C(1)); 2.16 (*ddm*, $J = 7.13$, 6.94, H–C(3)); 1.88 (*dd*, $J = 8.32$, 8.12, H–C(4)); 1.76 (*dm*, $J = 14.66$, 1 H–C(9)); 1.74 (*m*, H–C(2)); 1.43 (*dm*, $J = 14.66$, 1 H–C(9)); 1.26 (*t*, $J = 7.1$, *Me*CH$_2$O). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 169.96 (CO); 169.71 (CO); 79.40 (C(5)); 61.47 (MeCH$_2$O); 41.19 (C(8)); 31.51 (C(1)); 30.34 (C(9)); 26.48 (C(4)); 25.61 (C(3)); 24.95 (C(2)); 14.00 (*Me*CH$_2$O). CI-MS (CH_4): 239 (2, $[M+29]^+$), 212 (13, $[M+2]^+$), 211 (100, $[M+1]^+$), 193 (24), 183 (6), 166 (8), 165 (60), 151 (3), 138 (7), 137 (44). 119 (10), 93 (10), 91 (14), 79 (2), 57 (4), 43 (4). Anal. calc. for $C_{11}H_{14}O_4$: C 62.85, H 6.71; found: C 62.85, H 6.96.

*Ethyl (1*R*,2*R*,3*S*,4*S*,5*R*)-7-Oxo-6-oxatricyclo[3.3.1.0^{2,4}]nonane-3-carboxylate* (*anti*-**38**). As described for **33**, with *anti*-**11** (8.71 g, 44.84 mmol), $NaHCO_3$ (7.53 g, 89.69 mmol), CH_2Cl_2, and MCPBA (28.14 g, 89.69 mmol) (20 h). Purification as described for *syn*-**38** yielded 8.40 g (89%) of *anti*-**38**. White solid. M.p. 124–125°. $[\alpha]_D^{22} = +23.2$ ($c = 0.93$, $CHCl_3$). IR (KBr): 1723. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 4.81 (*m*, H–C(5)); 4.13 (*q*, $J = 7.13$, MeC*H*$_2$O); 2.78 (*dd*, $J = 18.36$, 4.41, 1 H–C(8)); 2.71 (*ddd*, $J = 18.36$, 1.97, 1.97, 1 H–C(8)); 2.57 (*m*, H–C(1)); 2.36 (*dm*, $J = 6.36$, H–C(4)); 1.99 (*ddm*, $J = 6.30$, 2.99, H–C(2)); 1.72 (*dm*, $J = 14.07$, 1 H–C(9)); 1.68 (*dd*, $J = 2.73$, 2.73, H–C(3)); 1.46 (*dm*, $J = 14.07$ Hz, 1 H–C(9)); 1.26 (*t*, $J = 7.13$, *Me*CH$_2$O). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 171.08 (CO); 169.37 (C(7)); 78.86 (C(5)); 60.94 (MeCH$_2$O); 40.35 (C(8)); 31.69 (C(1)); 29.54 (C(4)); 29.43 (C(9)); 28.59 (C(3)); 22.15 (C(2)); 14.11 (*Me*CH$_2$O). CI-MS (CH_4): 251 (1, $[M+41]^+$), 239 (4, $[M+$

29]$^+$), 212 (13, [$M+2$]$^+$), 211 (100, [$M+1$]$^+$), 210 (8, M^+), 193 (30), 183 (5), 166 (8), 165 (69), 137 (23), 119 (5), 107 (2), 93 (5), 91 (7), 41 (4). Anal. calc. for $C_{11}H_{14}O_4$: C 62.85, H 6.71; found: C 62.88, H 6.83.

Ethyl 3-Oxo-2-oxabicyclo[3.2.1]octane-7-exo-*acetate* (*rac*-**39**). A soln. of *rac-syn*-**38** (52 mg, 24.7 mmol) in MeOH (20 ml) was hydrogenated for 15 h at r.t./1 atm over 10% Pd/C (112 mg). The catalyst was filtered off, the filtrate evaporated, and the residue purified by CC (AcOEt/petroleum ether 1:1): 13 mg (25%) of *rac*-**39**. Colorless oil. ^{1}H-NMR (360 MHz, $CDCl_3$): 4.59 (*m*, H−C(5)); 4.15 (*q*, $J=7.13$, MeCH_2O); 2.85 (*m*, 1 H−C(6)); 2.75 (*ddd*, $J=18.54$, 5.13, 2.57, H−C(2)); 2.57 (*m*, H−C(1)); 2.51 (*dm*, $J=18.54$, H−C(2)); 2.36 (*dd*, $J=15.26$, 7.6, 1 H−C(6)); 2.20 (*dd*, $J=15.26$, 8.42, 1 H−C(6)); 2.09 (*ddd*, $J=13.69$, 8.56, 2.28, 1 H−C(7)); 1.96 (*dm*, $J=13.69$, 1 H−C(7)); 1.76 (*dm*, $J=13.12$, 1 H−C(8)); 1.49 (*dm*, $J=13.12$, 1 H−C(8)); 1.27 (*t*, $J=7.13$, *Me*CH_2O). NOE: 2.85 (2.8, 4.59), 2.36 (2.9, 4.59), 1.76 (1.6, 4.59), 4.59 (2.3, 2.85), 2.36 (1.7, 2.85), 2.20 (1.63, 2.85), 2.75 (4.2, 2.57), 1.76 (1.9, 2.57), 1.49 (20, 2.57). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 169.94 (CO); 83.81 (C(5)); 60.73 (CH_2O); 41.76 (C(6)); 40.24 (C(2)); 39.44 (*C*H_2COO); 37.29, 33.50 (C(7), C(8)); 32.41 (C(1)); 14.63 (*Me*CH_2O). CI-MS (CH_4): 212 (6, [$M+2$]$^+$), 213 (45, [$M+1$]$^+$), 196 (12), 195 (100), 184 (3), 167 (47), 154 (5), 153 (65), 139 (6), 121 (3), 93 (3), 41 (23).

*Methyl (1*R*,2*R*,4*R*,5*S*,6*S*)-4-Hydroxy-6-(methoxycarbonyl)bicyclo[3.1.0]hexane-2-acetate* (*anti*-**40**). A soln. of *anti*-**38** (8.30 g, 39.48 mmol) in MeOH (180 ml) containing 37% aq. HCl soln. (9.87 ml, 118.44 mmol) was refluxed for 48 h and then cooled and evaporated. The residual liquid was partitioned between AcOEt (100 ml) and H_2O (100 ml), the aq. layer extracted with AcOEt (4 × 100 ml), the combined org. extract washed with H_2O (100 ml) and brine (100 ml), dried (Na_2SO_4), and evaporated: 8.74 g (97%) of *anti*-**40** as a slightly yellow oil which was transformed into *anti*-**41** without further purification. IR ($CDCl_3$): 1724. ^{1}H-NMR (360 MHz, $CDCl_3$): 4.35 (*d*, $J=5.25$, 1 H−C(4)); 3.69 (*s*, MeO); 3.66 (*s*, MeO); 2.69–2.53 (*m*, 3 H); 2.07 (*m*, 1 H); 1.97 (*dd*, $J=5.81$, 3.00, 1 H); 1.64 (*ddd*, $J=15.32$, 6.93, 5.43, 1 H); 1.50 (*dm*, $J=15.32$, 1 H); 1.29 (*dd*, $J=3.18$, 3.00, 1 H). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 173.27 (CO); 172.97 (CO); 73.72 (C(4)); 51.76 (MeO); 51.56 (MeO); 40.39 (*C*H_2CO_2Me); 37.11 (C(3)); 36.09; 34.48; 32.45; 22.22. CI-MS (CH_4): 269 (1, [$M+41$]$^+$), 258 (2, [($M+29$)+1]$^+$), 257 (19, [$M+29$]$^+$), 229 (11, [$M+1$]$^+$), 228 (5, M^+), 212 (15), 211 (100), 197 (12), 180 (5), 179 (51), 152 (3), 151 (43), 137 (3), 119 (7), 91 (9).

rac-*Methyl 6-(Methoxycarbonyl)-4-oxobicyclo[3.1.0]hexane-2-acetate* (*syn*-**41**). As described for *anti*-**40**, with *rac-syn*-**38** (2.10 g, 10 mmol), MeOH (45 ml), and containing 37% aq. HCl soln. (2.5 ml, 30 mmol). The product, *rac-syn*-**40**, was added, without further purification, into a stirred suspension of PCC (3.14 g, 14.55 mmol) in CH_2Cl_2 (100 ml). After 2 h, dry Et_2O (100 ml) was added, and the supernatant liquid was decanted from a black gummy residue, which was washed with dry Et_2O (3 × 200 ml) until it became a black granular solid. The combined org. soln. was filtered through a short pad of *Florisil*, the filtrate evaporated, and the residue purified by CC (AcOEt/petroleum ether 1:2): 678.7 mg (30%) of *rac-syn*-**41**. Colorless oil. ^{1}H-NMR (200 MHz, $CDCl_3$): 3.717 (*s*, MeO); 3.707 (*s*, MeO); 2.86–2.67 (*m*, 2 H); 2.63–2.56 (*m*, 2 H); 2.35–2.24 (*m*, 3 H); 2.10–1.91 (*m*, 1 H). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 210.80 (C(4)); 171.74 (CO); 169.77 (CO); 52.08 (MeO); 51.52 (MeO); 44.68 (C(3)); 40.40 (*C*H_2COO); 34.34; 34.12; 30.12; 27.94. CI-MS (CH_4): 267 (3, [$M+41$]$^+$), 255 (5, [$M+29$]$^+$), 228 (7, [$M+2$]$^+$), 227 (56, [$M+1$]$^+$), 196 (12), 195 (100), 167 (10), 153 (5), 135 (5), 121 (3), 107 (4), 98 (3).

*Methyl (1*R*,2*R*,5*S*,6*S*)-6-(Methoxycarbonyl)-4-oxobicyclo[3.1.0]hexane-2-acetate* (*anti*-**41**). Crude *anti*-**40** (8.74 g, 38.30 mmol) was added in one portion to a stirred suspension of PCC (12.38 g, 57.45 mmol) in anh. CH_2Cl_2 (400 ml). After 2 h, the product (R_f 0.33) was isolated and purified as described for *syn*-**41**: 5.29 g (61%) of *anti*-**41**. White solid. M.p. 100.5–101.5°. $[\alpha]_D^{23}=+2.04$ ($c=1.03$, $CHCl_3$). IR (KBr): 1726. ^{1}H-NMR (360 MHz, $CDCl_3$): 3.71 (*s*, MeO); 3.70 (*s*, MeO); 2.86 (*m*, H−C(2)); 2.54 (*dd*, $J=16.26$, 7.41, 1 H, CH_2COO); 2.45 (*dd*, $J=16.26$, 7.13, 1 H, CH_2COO); 2.43 (*dd*, $J=5.56$, 3.57, H−C(5)); 2.32 (*m*, H−C(1)); 2.31 (*dd*, $J=19.11$, 8.85, 1 H−C(3)); 2.08 (*m*, H−C(6)); 1.88 (*dm*, $J=19.11$, 1 H−C(3)). NOE: 2.54 (2.07, 2.86), 2.45 (6.22, 2.86), 2.31 (4.77, 2.86), 2.08 (4.51, 2.86), 2.86 (4.33, 2.08). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 209.46 (C(4)); 171.56 (CO); 170.33 (CO); 52.26 (MeO); 51.70 (MeO); 39.73 (*C*H_2CO_2Me); 38.58 (C(3)); 35.00; 33.66; 31.90; 26.31. CI-MS (CH_4): 267 (2, [$M+41$]$^+$), 255 (5, [$M+29$]$^+$), 228 (5, [$M+2$]$^+$), 227 (49, [$M+1$]$^+$), 196 (10), 195 (100), 181 (4), 167 (10), 153 (8), 135 (7), 107 (8), 98 (18), 79 (1), 45 (5). Anal. calc. for $C_{11}H_{14}O_5$: C 58.40, H 6.24; found: C 58.47, H 6.25.

*Dimethyl (1*R*,2*R*)-4-Oxocyclopentane-1,2-diacetate* (**42**). A soln. of *anti*-**41** (3.51 g, 15.50 mmol) in MeOH (160 ml) was hydrogenated for 15 h at r.t./1 atm over 10% Pd/C (1.05 g). The catalyst was filtered off, the filtrate evaporated, and the residue purified by FC (AcOEt/petroleum ether 1:3): 3.22 g (91%) of **42**. Colorless oil. R_f 0.32. $[\alpha]_D^{23}=+136.2$ ($c=0.52$, $CHCl_3$). IR ($CHCl_3$): 1740, 1728. ^{1}H-NMR (360 MHz, $CDCl_3$): 3.69 (*s*, 2 MeO); 2.70–2.56 (*m*, CH_2(3), CH_2(5)); 2.39–2.28 (*m*, 2 CH_2COO); 2.06–1.96 (*m*, H−C(1), H−C(2)).

^{13}C-NMR (50.3 MHz, $CDCl_3$): 215.31 (C(4)); 172.12 (2 C, 2 CO); 51.58 (2 C, 2 MeO); 44.48 (2 C, C(3), C(5)); 38.19 (2 C, C(1), C(2)); 37.53 (2 C, 2 CH_2COO). CI-MS (CH_4): 269 (1, $[M+41]^+$), 257 (2, $[M+29]^+$), 229 (33, $[M+1]^+$), 198 (11), 197 (100, $[M-MeO]^+$), 183 (11), 169 (6), 168 (4), 155 (12). Anal. calc. for $C_{11}H_{16}O_5$: C 57.89, H 7.07; found: C 57.73, H 7.09.

*Dimethyl (1*R,*2*R*)-4-Hydroxycyclopentane-1,2-diacetate* (**43**). $NaBH_4$ (481 mg, 12.71 mmol) was added in one portion into a stirred soln. of **42** (2.90 g, 12.71 mmol) in MeOH (40 ml) at 0°. After 1 h stirring at 0°, most of the solvent was evaporated before H_2O (40 ml) was added. The mixture was extracted with AcOEt (5 × 40 ml), the combined extract washed with brine (50 ml), dried (Na_2SO_4), and evaporated, and the residue purified by CC (AcOEt/petroleum ether 1:1): 2.69 g (92%) of **43**. Colorless oil. R_f 0.36. $[\alpha]_D^{23} = +39.1$ ($c = 0.47$, $CHCl_3$). IR ($CHCl_3$): 1728. ^{1}H-NMR (360 MHz, $CDCl_3$): 4.33 (*m*, H–C(4)); 3.674 (*s*, MeO); 3.671 (*s*, MeO); 2.58 (*dd*, *J* = 15.76, 5.05, 1 H); 2.51 (*dd*, *J* = 14.27, 4.56, 1 H); 2.38 (*dd*, *J* = 15.76, 8.62, 1 H); 2.23 (*dd*, *J* = 14.27, 8.72, 1 H); 2.33–2.25 (*m*, 2 H); 2.00–1.92 (*m*, 2 H); 1.76 (br. *s*, OH); 1.53 (*ddd*, *J* = 13.72, 9.91, 5.75, 1 H); 1.40 (*dddd*, *J* = 13.72, 7.53, 3.57, 1.58, 1 H). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 173.43 (CO); 173.11 (CO); 71.99 (C(4)); 51.45 (2 MeO); 42.33, 41.64 (C(3), C(5)); 40.11, 39.39 (C(1), C(2)); 39.01, 38.62 (2 CH_2COO). CI-MS (CH_4): 259 (6, $[M+29]^+$), 231 (18, $[M+1]^+$), 214 (6), 213 (50), 199 (3), 182 (11), 181 (100), 167 (3), 153 (15), 152 (2), 139 (12). Anal. calc. for $C_{11}H_{18}O_5$: C 57.38, H 7.88; found: C 57.21, H 7.94.

*Methyl (1*R,*2*S,*4*S*)-2-{2-[[(*tert*-*Butyl)diphenylsilyl]oxy}ethyl]-4-[(methylsulfonyl)oxy]cyclopentaneacetate* (**44**). To a stirred soln. of **15b** (925 mg, 2.10 mmol) in CH_2Cl_2 (35 ml), Et_3N (533 mg, 5.26 mmol) and methanesulfonyl chloride (602 mg, 5.26 mmol) were successively added, and the mixture was stirred for 2 d at r.t. The residue obtained after evaporation was purified by CC (AcOEt/petroleum ether 1:2): 1.035 g (95%) of **44**. Colorless syrup. R_f 0.49. $[\alpha]_D^{23} = +29.8$ ($c = 0.47$, $CHCl_3$). IR ($CHCl_3$): 1732. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 7.67–7.63 (*m*, 4 arom. H); 7.45–7.36 (*m*, 6 arom. H); 5.10 (*m*, H–C(4)); 3.73–3.61 (*m*, CH_2CH_2O); 3.66 (*s*, MeO); 2.95 (*s*, $MeSO_2$); 2.57 (*dd*, *J* = 15.56, 3.94, 1 H); 2.44 (*ddd*, *J* = 14.65, 7.84, 6.50, 1 H); 2.25 (*dd*, *J* = 15.56, 9.48, 1 H); 2.17 (*m*, 1 H); 1.97–1.87 (*m*, 2 H); 1.81 (*m*, 1 H); 1.67 (*m*, 1 H); 1.51 (*ddd*, *J* = 14.40, 10.06, 6.08, 1 H); 1.37 (*m*, 1 H); 1.05 (*s*, ^{t}Bu). ^{13}C-NMR (125.76 MHz, $CDCl_3$): 173.11 (CO); 135.51, 133.65, 129.66, 127.68 (12 arom. C); 83.00 (C(4)); 62.52 (CH_2CH_2O); 51.60 (MeO); 40.29 ($MeSO_2$); 39.95 (C(1) or C(2)); 39.83, 39.31 (C(3), C(5)); 38.88 (CH_2CH_2O); 38.42 (C(2) or C(1)); 36.51 (CH_2CO_2Me); 26.82 (3 C, Me_3C); 19.13 (Me_3C). FAB-MS: 542 (2, $[M+Na]^+$), 520 (4, $[M+1]^+$), 488 (6), 461 (37), 441 (13), 421 (7), 391 (6), 365 (33), 345 (56), 277 (56), 257 (18), 239 (26), 213 (100), 183 (100), 137 (100). Anal. calc. for $C_{27}H_{38}OSSi$: C 62.52, H 7.38; found: C 62.37, H 7.49.

*Methyl (1*R,*2*R,*4*R*)-4-(6-Amino-9*H*-purin-9-yl)-2-{2-[[(*tert*-butyl)diphenylsilyl]oxy}ethyl}cyclopentaneacetate* (**45**). As described for **36**, with **44** (220 mg, 424 mmol): **45** (135 mg, 57%). White solid. M.p. 126–126.5° (from CH_2Cl_2/petroleum ether). R_f (CH_2Cl_2/EtOH 20:1) 0.20. $[\alpha]_D^{24} = +23.86$ ($c = 0.44$, $CHCl_3$). IR (KBr): 1738, 1669, 1643, 1601. UV ($CHCl_3$): 262 (15600). ^{1}H-NMR (500.13 MHz, $CDCl_3$): 8.35 (*s*, H–C(2′)); 7.84 (*s*, H–C(8′)); 7.67–7.63 (*m*, 4 arom. H); 7.44–7.35 (*m*, 6 arom. H); 5.86 (*s*, NH_2); 4.90 (*m*, H–C(4)); 3.77–3.62 (*m*, CH_2CH_2O); 3.67 (*s*, MeO); 2.60 (*dd*, *J* = 15.10, 3.48, 1 H); 2.42 (*m*, 1 H); 2.37–2.24 (*m*, 3 H); 2.13–2.05 (*m*, 1 H); 1.94–1.80 (*m*, 2 H); 1.68 (*m*, 1 H); 1.52 (*m*, 1 H); 1.05 (*s*, ^{t}Bu). ^{13}C-NMR (50.3 MHz, $CDCl_3$): 172.98 (CO); 155.18 (C(6′)); 152.29 (C(2′)); 150.01 (C(4′)); 138.64 (C(8′)); 135.50, 133.64, 129.67, 127.67 (12 arom. C); 119.95 (C(5′)); 62.40 (OCH_2CH_2); 53.78 (C(4′)); 51.63 (MeO); 41.11, 40.02 (C(1), C(2)); 39.52, 38.71, 38.07, 36.74, 26.87 (3 C, Me_3C); 19.16 (Me_3C). FAB-MS: 560 (11, $[M+2]^+$), 559 (38, $[M+1]^+$), 558 (87, M^+), 500 (23), 480 (5), 302 (10), 213 (27), 197 (34), 183 (23), 136 (100), 121 (34). Anal. calc. for $C_{31}H_{39}N_5O_3Si$: C 66.76, H 7.05, N 12.56; found: C 66.56, H 6.97, N 12.39.

*Methyl (1*R,*2*R,*4*R*)-2-{2-[[(*tert*-Butyl)diphenylsilyl]oxy}ethyl]-4-(1,2,3,4-tetrahydro-5-methyl-2,4-dioxopyrimidin-1-yl)cyclopentaneacetate* (**46**). As described for **37**, with **44** (210 mg, 405 mmol): **46** (77.8 mg, 35%). White foamy solid. M.p. 43–45°. R_f (AcOEt/CH_2Cl_2/EtOH 20:40:1) 0.62. $[\alpha]_D^{24} = +15.91$ ($c = 0.22$, $CHCl_3$). UV ($CHCl_3$): 272 (13400). IR (KBr): 1738, 1688. ^{1}H-NMR (500.13 MHz, $CDCl_3$): 8.81 (*s*, H–C(3′)); 7.66–7.62 (*m*, 4 arom. H); 7.45–7.36 (*m*, 6 arom. H); 7.00 (*d*, *J* = 1.17, H–C(6′)); 4.92 (*m*, H–C(4)); 3.75–3.60 (*m*, CH_2CH_2O); 3.67 (*s*, MeO); 2.56 (*dd*, *J* = 15.02, 3.30, 1 H); 2.19 (*dd*, *J* = 15.02, 9.90, 1 H); 2.18–2.10 (*m*, 2 H); 2.01–1.94 (*m*, 1 H); 1.93 (*d*, *J* = 1.17, Me–C(5′)); 1.91–1.82 (*m*, 2 H); 1.75–1.65 (*m*, 1 H); 1.43 (*m*, 1 H); 1.26 (*m*, 1 H); 1.05 (*s*, ^{t}Bu). ^{13}C-NMR (125.76 MHz, $CDCl_3$): 173.07 (CO); 163.54 (C(4′)); 150.93 (C(2′)); 136.52 (C(6′)); 135.51, 133.64, 129.68, 127.68 (12 arom. C); 111.12 (C(5′)); 62.33 (CH_2O); 54.03 (C(4)); 51.61 (MeO); 40.79, 40.30 (C(1), C(2)); 38.58, 38.46, 36.49, 36.43, 26.85 (3 C, Me_3C); 19.13 (Me–C(5′)); 12.60 (Me_3C). FAB-MS: 550 (3, $[M+1]^+$), 549 (8, M^+), 491 (23), 471 (23), 365 (6), 345 (11), 307 (15), 287 (10), 247 (11), 213 (34), 197 (52), 167 (29), 135 (100), 127 (68). HR-ESI-MS (MeOH/$CHCl_3$): 571.2596 ($C_{31}H_{40}N_2O_5SiNa^+$, $[M+Na]^+$; calc. 571.2599). Anal. calc. for $C_{31}H_{40}N_2O_5Si$: C 67.85, H 7.35, N 5.10; found: C 67.47, H 7.59, N 4.80.

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Received April 20, 2004