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CATALYTIC OSMYLATION OF ELECTRON POOR ALLYLIC ALCOHOLS AND ETHERS. A SYNTHETIC APPROACH TO BRANCHED CHAIN SUGARS

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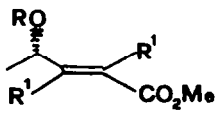
Abstract: The catalytic osmylation of electron-poor allylic ethers and alcohols was studied. In the case of γ-alkoxy E-enoates reaction selectivity was found to range from 2:1 to 8:1 in favor of the arabino (2,3-syn - 3,4-anti) product, regardless of the double bond substitution. Lower (if any) selectivity was found for the Z-isomers. On the contrary, 2-methylene-3-hydroxy esters were osmylated with virtually complete 2,3-syn selectivity.The factors affecting the stereochemical outcome of the reactions are discussed

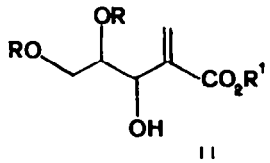
The relevance of the catalytic osmylation of allylic alcohols and ethers to the asymmetric synthesis of polyhydroxylated compounds has been recently recognized[1-4] and has stimulated an intensive effort of rationalization.[1,2a,3b,5,6] Different empirical rules have been proposed to predict the stereochemical outcome of the reaction.

As far as electron rich alkenes are concerned, the study of a large number of cases led Kishi to state that[1] "the relative stereochemistry between the preexisting hydroxy or alkoxy group and the adjacent, newly introduced hydroxy group of the major product, in all cases is "erythro" (anti).[7] For 4-alkoxy enoates and enones, instead, Stork proposed that the 3,4 - relative configuration of the mayor hydroxylation product depends upon double bond configuration, E and Z enoates being osmylated with apparently complete 3,4 - anti and 3,4 - syn selectivity respectively.[2a]

During the course of our studies directed toward the synthesis of rare sugars we decided to undertake an investigation of catalytic osmylation of alkoxy enoates of general formulae I and II with the aim of obtaining enantiomerically pure intermediates for branched-chain hexoses synthesis[8] and, at the same time, getting further information on enoate hydroxylation stereoselectivity.



I



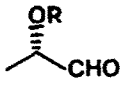
II

R = H, Alk

R¹ = H, Me

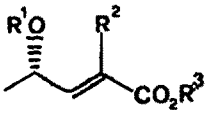
RESULTS AND DISCUSSION

Esters 3-10 were straightforwardly prepared starting from O-protected lactaldehydes 1[9] and 2[10] by Wittig-type reaction (see Table 1). Either stabilized ylides or Horner-Emmons reagents were employed for the synthesis of E-enoates, whereas Z-pentenoates were best prepared with the Still-Gennari reagent.[11] For comparison, ester 11 was synthesized as described by Stork.[2a] The synthesis of methylene esters 12 and 13 has been reported elsewhere.[12]

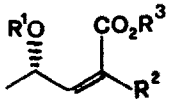


1 R = Bn

2 R = BOM

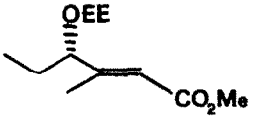


E- 3-10

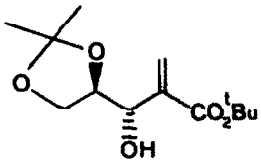


Z- 3-10

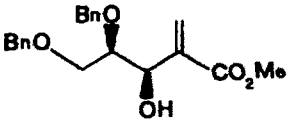
3	R^1 = Bn	R^2 = H	R^3 = Me
4	R^1 = BOM	R^2 = H	R^3 = Me
5	R^1 = H	R^2 = H	R^3 = Me
6	R^1 = Bn	R^2 = H	R^3 = Et
7	R^1 = Bn	R^2 = Me	R^3 = Me
8	R^1 = Bn	R^2 = Me	R^3 = Et
9	R^1 = BOM	R^2 = Me	R^3 = Et
10	R^1 = H	R^2 = Me	R^3 = Et



11



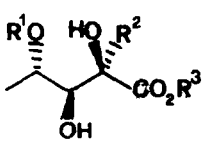
12



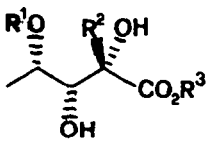
13

BOM = $C_6H_5CH_2OCH_2$
Bn = $C_6H_5CH_2$
EE = $CH(CH_3)OCH_2CH_3$

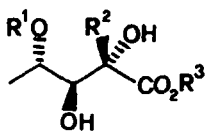
SCHEME 1.



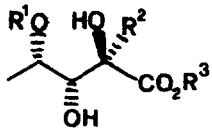
a arabino



b xylo

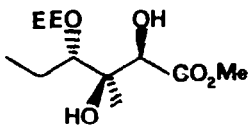


c ribo

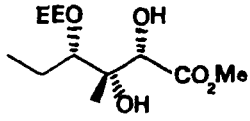


d lyxo

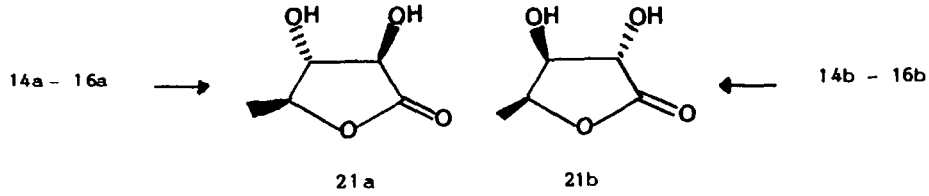
14a-d	R^1 = Bn	R^2 = H	R^3 = Me
15a-d	R^1 = BOM	R^2 = H	R^3 = Me
16a-b	R^1 = Bn	R^2 = H	R^3 = Et
17a-d	R^1 = Bn	R^2 = Me	R^3 = Me
18a-b	R^1 = Bn	R^2 = Me	R^3 = Et
19a-b	R^1 = BOM	R^2 = Me	R^3 = Et

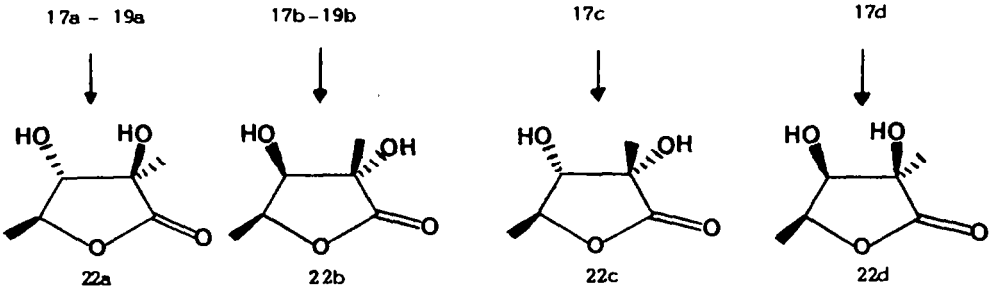


20a



20b





Catalytic osmylation[13] of olefins 3-13 occurs with high chemical yields, generally affording mixtures of isomeric diols. The relative configuration at product stereocenters was assigned by conversion to the corresponding γ-lactones (Scheme 1) whose structure can be established by ^{1}H- and ^{13}C-NMR spectroscopy on the basis of very characteristic trends of chemical shift and coupling constant

values.[14] The arabino configuration was assigned to 20a by Stork.[2a]

In the case of E-enoates (Table 2) diols 14-20 and lactones 21 were obtained in isomeric ratios ranging from 2:1 to 8:1. The predominant isomer showed, in all cases, the arabino (2,3-syn - 3,4-anti) configuration. Some dependence on the nature of R^1 (see Figure) was also evident: in the series 3-6 (Table 2, Entries 1-4) the best result was obtained with γ-hydroxy pentenoate 5 from which a 7:1 mixture of lactones 21a and 21b was isolated.

Occasionally the stereoselection in the series of 2-methyl-E-enoates is the same as that of 2-unsubstituted enoates in the case of protected hydroxyl groups, as observed for arabino-xylo ratios of E disubstituted pentenoates and the corresponding 2-methyl derivatives (cfr Table 2, Entries 1 vs 5, 4 vs 6). On the contrary no stereoselectivity is observed if, in position 4, there is a free hydroxyl group (Entry 8).

The ratio 20a : 20b which was not specified in Ref. 2a, was found to be 8:1.

Surprisingly,[2a] osmylations of Z-enoates were either non selective (Z-3 and Z-4, Table 3 Entries 1 and 2) or showed low preference for the ribo (2,3-anti - 3,4-anti) product (Z-7, Table 2, Entry 3).

Osmium tetroxide promoted hydroxylation of esters 12 and 13 (Scheme 2) provided the best stereochemical results: in both cases a single detectable triol (23 and 25 respectively) was generated. Product configurations were shown to be 2,3-syn by conversion into the known lactones 24 and 26.[15]

Since the mechanism of osmylation is not well defined,[16] the factors determining reaction selectivity are particularly difficult to evaluate. A rationalization of the results can be attempted on the basis of Stork's model for enoate osmylation.[2a] From this point of view, the 3,4-anti selectivity shown by E-enoates can be explained assuming that reaction takes place preferentially through transition structure A (Y=Z=H, X= CO_2R). This structure, which features an s-cis

TABLE 1. Synthesis of Enoates

Entry		Reagent	Reaction Conditions	Enoate	E:Z[a]
1	1	$Ph_3P{=}C(Me)CO_2Me$[b]	CH_2Cl_2/R.T.	7	15:1
2	1	$Ph_3P{=}C(Me)CO_2Et$[b]	" "	8	15:1
3	2	"	" "	9	15:1
4	1	$(MeO)_2P(=O)CH(Me)CO_2Me$	KH/THF/-78°C	7	1:1
5	1	$Ph_3P{=}CH_2CO_2Me$[b]	CH_2Cl_2/R.T.	3	1.7:1
6	2	"	" "	4	2.1:1
7	1	$(EtO)_2P(=O)CH_2CO_2Et$	NaH/THF/-78°C	6	12:1
8	1	"	NaH/THF/-40°C	6	19:1
9	1	$(MeO)_2P(=O)CH_2CO_2Me$	NaH/THF/-60°C	3	1:1
10	1	$(CF_3CH_2O)_2P(=O)CH_2CO_2Me$	$KN(SiMe_3)_2$/THF/ DCH-18-C-6/-78°C	3	1:5
11	2	"	$KN(SiMe_3)_2$/THF/-78°C	4	1:8
12	2	"	KH/THF/-78°C	4	1:9

a Ratios determined by HPLC and/or ^{1}H-NMR

b Ylide generated by 2N NaOH from the corresponding phosphonium salt

TABLE 2. Catalytic Osmylation of E-Enoates

Entry	Enoate	Product	Y %	R. Time (hours)	Diast. Ratio a : b
1	E-3	14a,b	70	12	3:1[a]
2	E-4	15a,b	76	12	2.2:1[a]
3	E-5	21a,b	70	4	7:1[a]
4	E-6	16a,b	75	24	3:1[a]
5	E-7	17a,b	88	2.5	3:1[a]
6	E-8	18a,b	85	2.5	3:1[b]
7	E-9	19a,b	94	3	2.2:1[b]
8	E-10	22a,b	95	8	1:1.2[a]
9	11	20a,b	85	12	8:1[a]

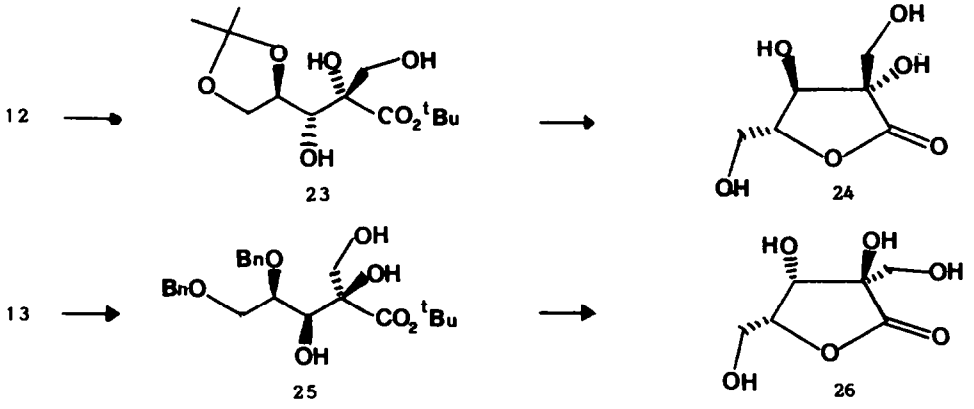
a. determined by ^{1}H-NMR and/or ^{13}C-NMR on the crude product
b. determined by isolation of products

TABLE 3. Catalytic Osmylation of Z-Enoates

Entry	Enoate	Product	Y %	R. Time (hours)	Diast. Ratio[a] c:d
1	Z-3	14c-d	85	15	1:1
2	Z-4	15c-d	85	12	1:1
3	Z-7	17c-d	91	12	1.7:1

a. determined by ^{1}H-NMR and/or ^{13}C-NMR on the crude product

SCHEME 2.



conformational arrangement between the olefinic linkage and the allylic C-O bond, is indeed suggested by Stork to be more stable than B because of favorable interaction between the system and an unshared electron pair on the γ-oxygen.

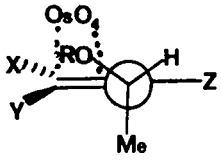
It is interesting to note that models A and B correspond to the most stable transition structures proposed by Houk for electrophilic attacks to double bonds on the basis of hyperconjugative effect considerations.[5] In accordance with Houk, the σ'-acceptor (OR) would occupy "inside" or "outside" positions and the best σ'-donor (CH_3) would be "anti" to the electrophile to facilitate olefin HOMO - electrophile LUMO interactions. Structures A and B should represent the best transition states for 2,3-syn - 3,4-anti and 2,3-syn - 3,4-syn allylic ether enoates hydroxylations respectively.

Structure A should be destabilized in Z-enoates and higher selectivity for 2,3-syn - 3,4-anti hydroxy groups would be expected for E-enoates.

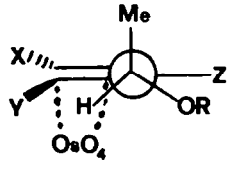
The formation of 2,3-syn diols from methylene esters 12 and 13 can as well be rationalized by transition structure A (X=Y=H, Z=CO_2Me). The exceptionally high selectivity observed can be tentatively explained considering that B should undergo a destabilizing carboxy-alkoxy interaction as a result of gem substitution and thus the energy gap between the suggested transition structures should be further increased.

On attempting a rationalization of the stereochemical outcome of Z-enoates hydroxylation, Stork proposed that the steric hindrance between two cis substituents should force the reaction to proceed through transition structure B (X=Z=H, Y=CO_2R), which is less sterically crowded than A . This should determine the inversion of diastereoface selection with respect to the E-isomers.

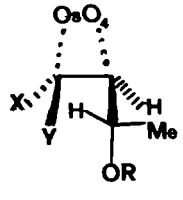
Such a prediction was verified in all the known cases .[1,2a,3a,4a] However, for most of the reports, result interpretation is blurred by the fact that they deal with rather complex molecules, where the allylic stereocenter is actually part of large, sugar-like appendages that can exert a significant influence on the reaction course. Although our results suggest that inversion of selectivity is not a necessary consequence of changing double bond configuration, they are in qualitative agreement with the proposed model. Indeed a comparison between Tables 2 and 3 shows that Z-enoates require longer reaction times and give lower isomeric ratios than the E-ones.



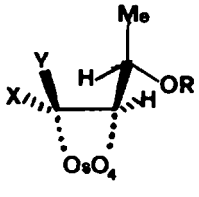
A



B



C



D

This seems to support the hypothesis that, for Z-isomers, structure A is strongly destabilized and B becomes the most important transition structure.

The steric effects can be better interpreted taking into account transition structures C and D, proposed by Vedejs[6] for sterically crowded electron rich olefins.

These models can be useful especially for explaining the stereochemical outcome of 2-methyl E or Z enoates (less electron poor with respect to the corresponding 2-unsubstituted enoates) and Z-enoates with X equal to hydrogen.

Recent findings by Houk et al. and Vedejs et al. attribute a steric role for allylic oxygen substituents rather than electronic effects.

In particular Vedejs[6] has demonstrated that hyperconjugative effects of allylic substituents are not important in osmylation of electron rich olefins.

In effect as shown by our data (Table 3), for Z-enoates the sterically dominant effects are between carbomethoxy group and C_4; consequently C_4-hydrogen is placed "inside" as in C or in D (Y=CO_2CH_3 ; X=H or CH_3).

A small selectivity is however observed with the preference of C on D only in the case of Z-7 (Y=CO_2CH_3 ; X=CH_3).

No selectivity was observed for Z-3 and Z-4 (Table 3).

In the series of 2-methyl-E-enoates, models C and D (Y=CH_3 ; X=CO_2CH_3) are both operating, with a preference for C when R is benzyl or benzyloxymethyl.

No selectivity is observed when R is hydrogen owing to the eqivalence between C and D.

EXPERIMENTAL SECTION.

^{1}H NMR spectra were recorded with a Varian XL-200 or Bruker WP-80 instrument and ^{13}C NMR spectra with a Varian XL-200 instrument, in the FT mode, using tetramethylsilane as internal standard. IR spectra were recorded with a Perkin-Elmer 457 spectrophotomer. Optical rotations were measured in 1-dm cells of 1-ml capacity using a Perkin-Elmer polarimeter. Silica gel 60 F_{254} plates (Merck) were used for analytic TLC; 270-400 mesh silica gel (Merck) was used for flash chromatography.[17] HPLC analyses were performed on a Varian 500 equipped with a LiChrosorb Column and a U.V. (254) detector using a Hewlett-Packard 3390 A integrator. Organic extracts were dried over Na_2SO_4 and filtered before removal of the solvent under reduced pressure. "Dry" solvents were distilled under dry N_2 just before use: Diethyl ether and tetrahydrofuran (THF) were distilled from sodium in the presence of benzophenone; CH_2Cl_2 was distilled from CaH_2; acetone was distilled from K_2CO_3. All reactions employing dry solvents were run under a nitrogen (from liquid N_2) atmosphere.

Synthesis of 2E-2-methylpent-2-enoates: general procedure.
A solution of the appropriate aldehyde (see Table 1) (0.430 mmol) in methylene chloride (1.1 ml) was added dropwise to a solution of the indicated ylide (see Table 1) (0.52 mmol) in methylene chloride (2.3 ml) at room temperature. After 2.5 hours, 2.5 ml of water were added. The organic layer was separated, dried and evaporated to dryness. Flash chromatography on silica gel with hexane/AcOEt 90:10 as eluant yielded olefins E-7 -E-9 (65-70%).

Methyl (2E)-(4S)-4-benzyloxy-2-methylpent-2-enoate E-7: $[\alpha]_D^{25}$=-53.3° (c=1.84 $CHCl_3$). IR ($CHCl_3$) ν :1705, 1645 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ :1.30 (3H, d, J=6.3Hz); 1.85 (3H, d, J=1.4Hz); 3.77 (3H, s); 4.28(1H, m); 4.44 (2H, m,); 6.69 (1H, dq, J=7.8, 6.3Hz); 7.30 (5H, s). (Found C,71.66; H,7.66; $C_{14}H_{18}O_3$ requires C,71.77; H,7.74).

Ethyl (2E)-(4S)-4-benzyloxy-2-methylpent-2-enoate E-8: $[\alpha]_D^{25}$=-54.6° (c=1.24 $CHCl_3$). IR ($CHCl_3$) ν :1705, 1650 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ : 1.29 (3H, d, J=6.6Hz); 1.31 (3H, t, J=7.5Hz); 1.82 (3H, d, J=1.4Hz); 4.20 (2H, q, J=7.5Hz); 4.32 (1H, m); 4.45 (2H,m), 6.80 (1H, dq, J=8.4, 6.6Hz); 7.30 (5H, s). ^{13}C-NMR ($CDCl_3$) selected data δ : 12.69; 60.60; 138.34; 142.86. (Found C,72.41; H,8.06; $C_{15}H_{20}O_3$ requires C,72.55; H,8.12).

Ethyl (2E)-(4S)- 4-benzyloxymethoxy-2-methylpent-2-enoate E-9: $[\alpha]_D^{25}$=-98.1° (c=1.00 $CHCl_3$). IR ($CHCl_3$) ν :1700, 1650 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ : 1.26 (3H, d, J=6.5Hz); 1.28 (3H, t, J=7.5Hz); 1.86 (3H, d, J=1.5Hz); 4.18 2H, q, J=7.5Hz); 4.48 (1H, m); 4.65 (2H, m); 6.62 (1H, m); 7.30 (5H, s). (Found C,69.19; H,8.01; $C_{16}H_{22}O_4$ requires C,69.04; H,7.97).

Synthesis of 2E-pentenoates: general procedure
Sodium hydride (1.0 mmol) was suspended in dry THF (2.0 ml) at the desired temperature (see Table 1) and the appropriate neat phosphonate (1.0 mmol) was added at this mixture. After 30 min a solution of the appropriate aldehyde (1.0 mmol) in THF (0.5 ml) was added dropwise. The mixture was stirred for 30-45 min, then diluted with diethyl ether (3 ml) and the reaction quenched with saturated aqueous ammonium chloride (3 ml). The temperature was made to rise to +25°C, then the organic layer was separated, washed with brine, dried and evaporated to dryness. Flash chromatography on silica gel with hexane/AcOEt 95:5 as eluant yielded olefins E-3, E-4, E-6 (70-75%).

Methyl (2E)-(4S)-4-benzyloxypent-2-enoate E-3: ^{1}H-NMR ($CDCl_3$) δ: 1.38 (3H, d, J=6.3Hz); 3.75 (3H, s); 4.10 (1H, m); 4.30-4.70 (2H, AB_{syst} ν_A=4.40, ν_B=4.60, J_{AB}=11.5Hz); 6.00 (1H, dd, J=16.0, 1.4Hz); 6.90 (1H, dd, J=16.0, 5.9Hz); 7.30 (5H, s). (Found, C,70.85; H,7.30; $C_{13}H_{16}O_3$ requires C,70.89; H,7.32).

Methyl (2E)-(4S)-4-benzyloxymethoxypent-2-enoate E-4: ^{1}H-NMR ($CDCl_3$) δ: 1.30 (3H, d, J=6.3Hz); 3.72 (3H, s); 4.40 (1H, m); 5.90 (1H, d br, J=15.2Hz); 6.88 (1H, dd, J=6.0, 15.2Hz); 7.30 (5H, s). (Found C,67.01; H,7.30; $C_{14}H_{18}O_4$ requires C,67.18; H,7.25).

Ethyl (2E)-(4S)-4-benzyloxypent-2-enoate E-6: ^{1}H-NMR ($CDCl_3$) δ: 1.30 (3H, t, J=7.8Hz); 1.38 (3H, d, J=6.0Hz); 4.20 (1H, m); 4.25 (4H, q, J=7.8Hz); 4.30-4.70 (2H, AB_{syst} ν_A=4.40 ν_B=4.60, J_{AB}=11.5Hz); 6.00 (1H, dd, J=15.8, 1.3Hz); 6.90 (1H, dd, J=6.0, 15.8Hz); 7.30 (5H, s). (Found C,71.60; H,7.68; $C_{14}H_{18}O_3$ requires C,71.77; H,7.74).

Synthesis of methyl (2E)-(4S)-4-hydroxypent-2-enoate E-5.
Concentrated HCl (0.15 ml) was added dropwise to a solution of 4 (22 mg, 0.090 mmol) in THF (0.73 ml). The mixture was stirred for 24 hours. Then the reaction was quenched with $NaHCO_3$ (290 mg) and extracted with Et_2O (3X3 ml); the organic layer was washed with brine, dried and evaporated to dryness. Flash chromatography on silica gel with hexane/AcOEt 70:30 as eluant yielded E-5 (10.0 mg, 85%).

E-5: ^{1}H-NMR ($CDCl_3$ + D_2O) δ: 1.32 (3H, d, J=6.4Hz); 3.73 (3H, s); 4.48 (1H, m br); 6.00 (1H, dd, J=15.2, 1.3Hz); 6.95 (1H, dd, J=15.2, 4.6Hz). (Found C,55.42; H,7.71; $C_6H_{10}O_3$ requires C,55.37; H,7.75).

Synthesis of ethyl (2E)-(4S)-4-hydroxy-2-methylpent-2-enoate E-10.
The reaction was carried out as for E-5. Flash chromatography on silica gel with hexane/AcOEt 75:25 yielded E-10 (90%).

E-10: ^{1}H-NMR ($CDCl_3$ + D_2O) δ: 1.28 (3H, t, J=7.2Hz); 1.30 (3H, d, J=6.4Hz); 1.85 (3H, d, J=1.5Hz); 4.19 (2H, q, J=7.2Hz); 4.66 (1H, dq, J=6.4, 8.1Hz); 6.67 (1H, dq, J=8.1, 1.5Hz). (Found C, 60.66; H,8.84; $C_8H_{14}O_3$ requires C,60.74; H,8.92).

Synthesis of 2Z-pentenoates: general procedure.
Potassium hydride (1.0 mmol) was suspended in dry THF (2.0 ml) at -78°C. A solution of the appropriate phosphonate (see Table 1) (1.0 mmol) in THF (2.0 ml) was added dropwise. After 40 min a solution of the indicated aldehyde (1.0 mmol) in THF (2.0 ml) was added dropwise. The mixture was stirred for 40 min then diluted with Et_2O (3 ml) and the reaction quenched with saturated aqueous ammonium chloride (3 ml). The temperature was made to rise to +25°C, then the organic layer was separated, washed with brine, dried and evaporated under reduced pressure. Flash chromatography on silica gel with hexane/ AcOEt 90:10 as eluant yielded olefins Z-3, Z-4, Z-7 (70-75%).

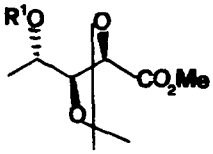
Z-3: ^{1}H-NMR ($CDCl_3$) δ: 1.20 (3H, d, J=6.3Hz); 3.68 (3H, s); 4.45 (2H, s); 5.13 (1H, m); 5.83 (1H, dd, J=1.1, 11.9Hz); 6.22 (1H, dd, J=8.3, 11.9Hz); 7.30 (5H, s). (Found C,70.76; H,7.31; $C_{13}H_{16}O_3$ requires C,70.89; H,7.32).

Z-4: ^{1}H-NMR ($CDCl_3$) δ: 1.30 (3H, d, J=6.3Hz); 3.70 (3H, s,); 4.60 (2H, s); 4.75 (2H, s); 5.36 (1H, m); 5.78 (1H, dd, J=1.0, 11.5Hz); 6.22 (1H, dd, J=8.0, 11.5 Hz); 7.30 (5H, s). (Found C,67.15; H,7.18 $C_{14}H_{18}O_4$ requires C,67.18; H,7.25).

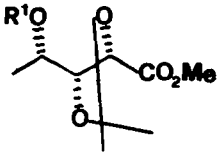
Z-7: ^{1}H-NMR ($CDCl_3$) δ: 1.30 (3H, d, J=6.3Hz); 1.95 (3H, s); 3.70 (3H, s); 4.44 (2H, m); 4.81 (1H, m); 5.91 (1H, d br, J=8.6Hz); 7.30 (5h, s). (Found C, 71.85; H,7.72; $C_{14}H_{18}O_3$ requires C,71.77; H,7.74).

Catalytic osmylation: general procedure.
A solution of osmium tetraoxide in t-butanol (0.039 M, 2.56 ml, 0.10 mmol) was added dropwise to a solution of trimethylamine-N-oxide dihydrate (222 mg; 2.0 mmol) in acetone:water 8:1 (2.0 ml) at room temnperature. To the oxidizing mixture a solution of the olefin (2.0 mmol) in acetone:water 8:1 (3.3 ml) was added. The solution was stirred for 3-24 hours (see Table 2), then sodium sulphite (2.0 mmol) was added and the suspension stirred for an hour. The inorganic salts were filtered off and washed with CH_2Cl_2; the crude product was evaporated, analyzed and characterized as reported below.

Osmylation of E-3.
The reaction yielded an inseparable mixture of diols 14 a,b, whose ratio was determined by integration of ^{1}H-NMR methyl ester signals (3.78 ppm 14a, 3.70 ppm 14b). The mixture was then dissolved in acetone and treated with toluene-4-sulfonic acid (0.05 eq) and $CuSO_4$ (1.0 eq) at room temperature overnight. The acetonides 28 and 29 were separated by flash chromatography on silica gel with hexane/AcOEt 90:10 and characterized by ^{1}H-NMR. From 14a, 28 was obtained; and from 14b, 29.
(2R)-(3S)-(4S)-2,3-O-isopropylidene-4-O-benzylarabinonic acid methyl ester 28: ^{1}H-NMR ($CDCl_3$) δ: 1.24 (3H, d, J=6.5Hz); 1.43 (3H, s); 1.45 (3H, s); 3.72 (1H, s); 3.72 (1H, m); 4.25 (1H, dd, J=4.5, 7.0Hz); 4.44 (1H, d, J=7.0Hz); 4.60 (2H, m); 7.30 (5H, s). (Found C,65.18; H,7.48 $C_{16}H_{22}O_5$ requires C,65.29; H,7.53).
(2S)-(3R)-(4S)-2,3-O-isopropylidene-4-O-benzylxylonic acid methyl ester 29: ^{1}H-NMR ($CDCl_3$) δ: 1.26 (3H, d, J=6.5Hz); 1.43 (3H, s); 1.47 (3H, s); 3.72 (1H, m); 3.73 (3H, s); 4.25 (1H, dd, J=7.0, 4.0Hz); 4.48 (1H, d, J=7.0Hz); 4.62 (2H, m); 7.30 (5H, s). (Found C,65.33; H, 7.55; $C_{16}H_{22}O_5$ requires C,65.29; H,7.53).



28 R^1=Bn
30 R^1=BOM



29 R^1=Bn
31 R^1=BOM

Osmylation of E-4.
The reaction yielded an inseparable mixture of diols 15a,b, whose ratio was determined by ^{13}C-NMR. ^{13}C-NMR ($CDCl_3$) selected data: 15a δ:52.9, 70.0, 73.8, 75.0, 93.4, 174.1. 15b δ: 52.8, 69.8, 71.0, 75.6, 94.5, 173.4.
The diols were transformed into the corresponding acetonides as reported for E-3; from 15a, 30 was obtained; from 15b, 31.
(2R)-(3S)-(4S)-2,3-O-isopropylidene-4-O-benzyloxymethoxyarabinonic acid methyl ester 30: ^{1}H-NMR ($CDCl_3$) δ: 1.27 (3H, d, J=6.5Hz); 1.45 (3H, s); 1.50 (3H, s); 3.80 (3H, s); 3.85-4.60 (3H, m); 4.63 (2H, s); 4.83 (2H, s); 7.30 (5H, s). (Found C,62.87; H,7.45; $C_{17}H_{24}O_6$ requires C,62.95; H,7.46).
(2S)-(3R)-(4S)-2,3-O-isopropylidene-4-O-benzyloxymethoxyxylonic acid methyl ester 31: ^{1}H-NMR ($CDCl_3$) δ: 1.29 (3H, d, J=6.5Hz); 1.43 (3H, s); 1.50 (3H, s); 3.80 (3H, s); 3.85-4.60 (3H, m); 4.58 (2H, s); 4.85 (2H, s); 7.30 (5H, s). (Found C,63.07; H,7.45; $C_{17}H_{24}O_6$ requires C,62.95; H,7.46).

Osmylation of E-5.
The reaction yielded an inseparable mixture of the corresponding lactones 21a,b, whose ratio was determined by ^{13}C-NMR. (Found C,45.51; H,6.10; $C_5H_8O_4$ requires C,45.46; H,6.10).
(2R)-(3S)-(4S)-5-deoxyarabinono-1,4-lactone 21a: ^{1}H-NMR (D_2O) δ: 1.50 (3H, d, J=5.9Hz); 4.01 (1H, dd, J=9.2, 8.5Hz); 4.07 (1H, d, J=8.5Hz); 4.48 (1H, dq, J=9.2, 5.9Hz); ^{13}C-NMR (D_2O) δ: 17.85, 74.61, 78.78, 79.45, 177.0.
(2S)-(3R)-(4S)-5-deoxyxylono-1,4-lactone 21b: ^{13}C-NMR (D_2O) selected data: δ: 14.79, 72.64, 74.01, 79.07.

Osmylation of E-6.
The reaction yielded an inseparable mixture of diols 16a,b, whose ratio was determined by ^{13}C-NMR. (Found C,62.66; H,7.51; $C_{14}H_{20}O_5$ requires C,62.67; H,7.51).
16a: ^{13}C-NMR ($CDCl_3$) selected data:
δ: 14.1; 62.1, 70.1, 71.4, 75.1, 75.5, 138.1, 173.8.
16b: ^{13}C-NMR ($CDCl_3$) selected data: δ :15.3, 62.0, 70.7, 71.2, 75.3, 75.6, 137.9, 173.0.

Osmylation of E-7.
The diols were separated by flash chromatography on silica gel with hexane/AcOEt

70:30 as eluant.

(2R)-(3S)-(4S)-4-O-benzyl-2-C-methyl-5-deoxyarabinonic acid methyl ester 17a: $[\alpha]_D^{25}$=+26.1° (c=0.435 $CHCl_3$). IR ($CHCl_3$) ν : 3540-3480, 1730, 1450, 1250 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ : 1.35 (3H, d, J=6.3Hz); 1.45 (3H, s); 2.55 (1H, m br); 3.50-3.70 (2H, m); 3.70 (3H, s); 4.02 (1H, s br); 4.36 (1H, d, J=11.2Hz); 4.62 (1H, d, J=11.2Hz); 7.30 (5H, s). (Found C,62.56; H,7.56; $C_{14}H_{20}O_5$ requires C,62.67; H,7.51).

(2S)-(3R)-(4S)-4-O-benzyl-2-C-methyl-5-deoxyxylonic acid methyl ester 17b: $[\alpha]_D^{25}$=+32.2° (c=0.490 $CHCl_3$). IR ($CHCl_3$) ν : 3570, 3520, 1730, 1450, 1250 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ : 1.30 (3H, d, J=6.3Hz); 1.50 (3H, s); 2.77 (1H, d, J=11.5Hz); 3.40 (1H, dd, J=11.5, 1.9Hz); 3.42 (3H, s); 3.61 (1H, s); 3.95 (1H, dq, J=6.4, 1.9Hz); 4.23 (1H, d, J=10.7Hz); 4.57 (1H, d, J=10.7Hz); 7.30 (5H, s). (Found C,62.54; H,7.55; $C_{14}H_{20}O_5$ requires C,62.67; H,7.51).

Osmylation of E-8.

The diols were separated as reported for E-7.

(2R)-(3S)-(4S)-4-O-benzyl-2-C-methyl-5-deoxyarabinonic acid ethyl ester 18a: $[\alpha]_D^{25}$=+23.2° (c=1.570 $CHCl_3$). IR ($CHCl_3$) ν : 3550, 3480, 1720, 1445, 1255 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ : 1.25 (3H, t, J=6.7Hz); 1.34 (3H, d, J=6.3Hz); 1.43 (3H, s); 2.61 (1H, m); 3.50-3.80 (2H, m); 4.18 (2H, q, J=6.7); 4.25 (1H, s br); 4.36 (1H, d, J=11.8Hz); 4.60 (1H, d, J=11.8Hz); 7.30 (5H, s). (Found C,63.88; H,7.93; $C_{15}H_{22}O_5$ requires C,63.81; H,7.85).

(2S)-(3R)-(4S)-4-O-benzyl-2-C-methyl-5-deoxyxylonic acid ethyl ester 18b: $[\alpha]_D^{25}$=+27.1° (c=0.520 $CHCl_3$). IR ($CHCl_3$) ν : 3570, 3520, 1730, 1445, 1255 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ : 1.08 (3H, t, J=6.7Hz); 1.30 (3H, d, J=9.6 Hz); 1.47 (3H, s); 2.77 (1H, d, J=11.4Hz); 3.42 (1H, dd, J=11.4, 1.6Hz); 3.63 (1H, s); 3.90 (2H, q, J=6.7Hz); 3.94 (1H, dq, J=9.6, 1.6Hz); 4.23 (1H, d, J=10.9Hz); 4.56 (1H, d, J=10.9Hz); 7.30 (5H, s). (Found C,63.90; H,7.89; $C_{15}H_{22}O_5$ requires C,63.81; H,7.85).

Osmylation of E-9.

The diols were separated as reported for E-7.

(2R)-(3S)-(4S)-4-O-benzyloxymethoxy-2-C-methyl-5-deoxyarabinonic acid ethyl ester 19a: IR ($CHCl_3$) ν : 3525, 3500, 1725, 1450, 1220 cm^{-1}. ^{1}H-NMR ($CDCl_3$) δ :1.27 (3H, t, J=6.7Hz); 1.31 (3H, d, J=6.4Hz); 1.40 (3H, s); 2.62 (1H, m); 3.70-4.20 (2H, m); 3.80 (1H, s br); 4.22 (2H, q, J=6.7Hz); 4.61 (2H, s); 4.78 (2H, s); 7.30 (5H, s). (Found C,61.48; H,7.66; $C_{16}H_{24}O_6$ requires C,61.52; H,7.74).

(2S)-(3R)-(4S)-4-O-benzyloxymethoxy-2-C-methyl-5-deoxyxylonic acid ethyl ester 19b: ^{1}H-NMR ($CDCl_3$) δ :1.30 (3H, t, J=6.7Hz); 1.32 (3H, d, J=6.11Hz); 1.47 (3H, s); 2.85 (1H, d br, J=10.7Hz); 3.43 (1H, d, J=1.6Hz); 3.50 (1H, s br); 4.15 (1H, m); 4.19 (2H, q, J=6.7Hz); 4.59 (2H, s); 4.71 (2H, s); 7.30 (5H, s). (Found C,61.43; H,7.70; $C_{16}H_{24}O_6$ requires C,61.52; H,7.74).

Osmylation of E-10.

The reaction yielded the corresponding lactones 22a,b whose ratio was determined by ^{13}C-NMR. (See above).

Osmylation of Methyl (2E)-(4S)-4-ethoxyethyl-3-methylex-2-enoate E-11.

The reaction yielded an inseparable mixture of four diols, whose ratio was determined by ^{13}C-NMR. (Found C,54.61; H,9.10; $C_{12}H_{24}O_6$ requires C,54.53; H,9.15). ^{13}C-NMR ($CDCl_3$) selected data: two mayor diastereoisomers δ: 11.7, 11.8, 15.0, 15.2, 61.3, 62.6, 101.3, 102.7. Two minor diastereoisomers δ: 10.9, 11.1, 15.5, 61.0, 62.3, 100.5, 103.0.

Osmylation of Z-3.

The reaction yielded an inseparable mixture of diols 14c,d whose ratio was determined by ^{1}H-NMR integration of methyl ester: ν_H: 3.55 (3H, s), 3.74 (3H, s). (Found C,61.37; H,7.03; $C_{13}H_{18}O_5$ requires C,61.40; H,7.13).

Osmylation of Z-4.

The reaction yielded an inseparable mixture of diols 15c,d whose ratio was determined by ^{1}H-NMR integration of methyl ester: ν_H: 3.70 (3H, s), 3.78 (3H, s). (Found C,59.12; H,7.02; $C_{14}H_{20}O_6$ requires C,59.14; H,7.09).

Osmylation of Z-7.

The diols were purified by flash chromatography on silica gel with hexane/AcOEt 50:50 as eluant. The ratio was determined by ^{1}H-NMR integration of the crude product.

(2S)-(3S)-(4S)-4-O-benzyl-2-C-methyl-5-deoxyribonic acid methyl ester 17c: ^{1}H-NMR ($CDCl_3$) δ : 1.32 (3H, d, J=6.2Hz); 1.40 (3H, s); 2.12 (1H, s br); 3.38 (3H, s);

3.42-3.62 (3H, m); 4.35 (2H, m); 7.30 (5H, s). (Found C,62.73; H,7.61; $C_{14}H_{20}O_5$ requires C,62.67; H,7.51).

(2R)-(3R)-(4S)-4-O-benzyl-2-C-methyl-5-deoxylyxonic acid methyl ester 17d: ^{1}H-NMR ($CDCl_3$) δ : 1.32 (3H, d, J=6.2Hz); 1.45 (3H, s); 2.80 (1H, s br); 3.48-3.90 (3H, m); 3.65 (3H, s); 4.40 (2H, m); 7.30 (5H, s). (Found C,62.51; H,7.47; $C_{14}H_{20}O_5$ requires C,62.67; H,7.51).

Osmylation of (3R)-(4R)-4,5-O-isopropylidene-2-deoxy-2-C-methylenarabinonic acid t-butyl ester 12.
To a solution of N-methylmorpholine N-oxide (135 mg, 1 mmol) and OsO_4 (0.6 ml of a 0.039 M solution in t-BuOH, 0.025 mmol) in 8:1 acetone-H_2O (1 ml) was added a solution of hydroxy ester 12 (129 mg, 0.5 mmol) in 8:1 acetone - H_2O (1.4 ml). The reaction was stirred overnight at room temperature and then Na_2SO_3 (35 mg, 0.22 mmol) was added. The mixture was stirred 1 hour, the solvent was evaporated and the crude product purified by flash chromatography on silica gel with hexane/AcOEt 30:70 as eluant to give 23 as a white solid (139 mg, 95%).

(2S)-(3R)-(4R)-4,5-O-isopropylidene-2-C-hydroxymethylarabinonic acid t-butyl ester 23: mp 95°C. $[\alpha]_D^{25}$=+22.1° (c=0.98 MeOH). IR ($CHCl_3$) ν : 3550, 3470, 1725, 1280, 1250, 1150, 1050, cm^{-1}. ^{1}H-NMR (Me_2SO-d6) δ :1.30 (3H, s); 1.35 (3H, s); 1.46 (9H, s); 3.44-3.65 (2H, m); 3.71 (1H, dd, J=10.5, 8.0Hz); 3.89 (1H, d, J=9.5Hz); 3.90 (1H, d, J=7.0Hz); 4.11 (1H, ddd, J=8.0, 7.0, 9.5Hz); 4.44 (1H, s); 4.66 (1H, m); 5.08 (1H, d, J=10.5Hz). ^{13}C-NMR ($CDCl_3$) selected data: δ : 25.43, 26.48, 27.89, 64.89, 66.52, 73.17, 75.21, 80.50, 83.39, 129.04, 172.28. (Found C,53.35; H,8.25; $C_{13}H_{24}O_7$ requires C,53.41; H,8.28).

Osmylation of (3S)-(4R)-4,5-O-dibenzyl-2-deoxy-2-C-methylenxylonic acid methyl ester 13.
The triol 25 was purified by flash chromatography on silica gel with hexane/AcOEt 50:50 as eluant (90%).

(2R)-(3S)-(4R)-4,5-O-dibenzyl-2-C-hydroxymethylxylonic acid t-butyl ester 25: mp 75°C. $[\alpha]_D^{25}$=+11.1° (c=2.50 $CHCl_3$). ^{1}H-NMR ($CDCl_3$+D_2O) δ : 3.40 (3H, s); 3.68-4.10 (4H, m); 3.88 (2H, m); 4.52 (2H, m); 4.53 (2H, s); 7.30 (10H, m). ^{13}C-NMR ($CDCl_3$) selected data δ : 52.8, 66.4, 70,2; 73.0, 73.5, 73.8, 75.0, 78.1, 174.5. (Found C,66.53; H,7.38; $C_{24}H_{32}O_7$ requires C,66.65; H,7.46).

Synthesis of (2S)-(3R)-(4R)-2-C-hydroxymethylarabinono-1,4-lactone 24.
A solution of 23 (800 mg, 2.74 mmol) in 70% aqueous AcOH (18 ml) was stirred at 50° C for 1 hour. The solution was then cooled to room temperature, 12 N HCl (0.45 ml) was added, and the reaction was stirred overnight at this temperature before adding a second portion of 12 N HCl (0.4 ml). After 2 hours AcONa (2.4 g) was added, the solvent evaporated, and the crude product purified by flash chromatography on silica gel with acetone/CH_2Cl_2 70:30 as eluant to give 24 as a syrup (320 mg, 66%).
24: $[\alpha]_D^{25}$=+59° (c=1.02 H_2O). IR ν :1780 cm^{-1}. ^{1}H-NMR (Me_2SO-d_6+D_2O) δ :3.34-3.56 (2H, m); 3.76 (2H, AB_{syst}, J=5.0Hz); 4.1 (1H, d, J=5.0Hz); 4.15-4.22 (1H, m). ^{13}C-NMR (D_2O) δ : 60.74, 62.23, 74.52, 79.16, 83.09. (Found C,40.41; H,5.72; $C_6H_{10}O_6$ requires C,40.46; H,5.66).

Hydrolysis wiyh aqueous ammonia gave a solution of ammonium 2-C-(hydroxymethyl)-D-arabonate, $[\alpha]_D^{25}$=+13° (c=0.5 in 1N NH_4OH) (lit.[15] for the L-isomer $[\alpha]_D^{25}$ =-11.5° (c=1.2 in 1N NH_4OH)).

Synthesis of (2R)-(3S)-(4R)-2-C-hydroxymethylxylono-1,4-lactone 26; 21a,b; (2R)-(3S)-(4S)-2-C-methyl-5-deoxyarabinono-1,4-lactone 22a, (2S)-(3R)-(4S)-2-C-methyl-5-deoxyxylono-1,4-lactone22b, (2S)-(3S)-(4S)-2-C-methyl-5-deoxyribono-1,4-lactone 22c, (2R)-(3R)-(4S)-2-C-methyl-5-deoxylyxono-1,4-lactone 22d.
2,3-diolpentanoates (1 mmol) were hydrogenated in the presence of 10% Pd-C (0.05 mmol) in ethanol for 3 hours, then palladium was filtered off and washed with ethyl alcohol. Evaporation of the solvent afforded the pure lactones 26, 21a,b and 22a-d.
26: $[\alpha]_D^{25}$=+65.5° (c=0.5 D_2O). ^{1}H-NMR (Me_2SO-d6) δ : 2.8-3.9 (6H, m); 4.12 (1H, d, J=9.7Hz, OH 2); 4.45(1H, t, J=5.7Hz, OH 1); 4.75 (1H, t, J=5.7Hz, OH 1); 5.00 (1H, s, OH 3).[18] (Found C,40.42; H,5.68; $C_6H_{10}O_6$ requires C,40.46; H,5.66).

21a,b: See above.

22a: $[\alpha]_D^{25}$=+44.0° (c=0.87 CH_3OH). ^{1}H-NMR (Me_2SO-d6) δ : 1.14 (3H, s); 1.31 (3H, d, J=6.3Hz); 3.69 (1H, dd, J=7.5, 5.2Hz); 4.02 (1H, dq, J=7.5, 6.3Hz); 5.74 (1H, s); 5.76 (1H, d, J=5.2Hz). (Found C,49.38; H,6.82; $C_6H_{10}O_4$ requires C,49.31; H,6.90).

22b: ^{1}H-NMR (Me_2SO-d6) δ : 1.21 (3H, s); 1.22 (3H, d, J=6.5Hz); 3.70 (1H, dd,

J=5.4, 3.5Hz); 4.72 (1H, dq, J=6.5, 3.5Hz); 5.53 (1H, d, J=5.4Hz); 5.97 (1H, s). (Found C,49.25; H,6.84; $C_6H_{10}O_4$ requires C,49.31; H,6.90).

22c: ^{1}H-NMR (CD_3OD) δ : 1.40 (6H, m); 3.56 (1H, d, J=7.4Hz); 4.35 (1H, dq, J=7.4, 6.4Hz). ^{13}C-NMR ($CDCl_3$) δ : 18.1 (Me_5), 22.0 (Me_2), 72.6, 78.5, 80.5, 176.6. (Found C,49.42; H,6.89; $C_6H_{10}O_4$ requires C,49.31; H,6.90).

22d: ^{1}H-NMR (CD_3OD) δ : 1.40 (6H, m); 3.90 (1H, d, J=3.0Hz); 4.65 (1H, dq, J=3.0, 6.0Hz). ^{13}C-NMR ($CDCl_3$) δ : 13.9 (Me_5); 21.4 (Me_2), 75.0, 75.4, 178.5. (Found C,49.21, H, 6.91; $C_6H_{10}O_4$ requires C,49.31; H,6.90).

NOTES AND REFERENCES

1. J.K.Cha, W.J.Christ and Y.Kishi Tetrahedron Lett. 3943 (1983); W.J.Christ, J.K.Cha and Y.Kishi Tetrahedron Lett. 3947 (1983).
2. a) G.Stork and M.Kahn Tetrahedron Lett. 3951 (1983); b) G.Stork and S.D.Rychnovsky Pure & Appl.Chem. 58, 767 (1986).
3. a) S.J.Danishefsky and M.P.De Ninno J.Org.Chem. 51, 2615 (1986); b) S.J.Danishefsky, E.Larson and J.P.Springer J.Am.Chem.Soc. 107, 1274 (1985).
4. a) J.S.Brimacombe, R.Hanna, A.K.M.S.Kabir, F.Bennet and I.D.Taylor J.Chem.Soc.Perkin Trans I, 815 (1986); b)J.S.Brimacombe, R.Hanna and A.K.M.S.Kabir ibid 823 (1986); J.S.Brimacombe, A.K.M.S.Kabir and I.D.Taylor Carbohydrate Res. 140, c9, (1985); J.S.Brimacombe, R.Hanna and F.Bennet ibid 135, c17(1985).
5. K.N.Houk, S.R.Moses, Y.-D.Wu, N.G.Rondan, V.Jager, R.Schohe and R.Fronczek J.Am.Chem.Soc. 106, 3880, (1984); K.N.Houk, H.-Y.Duh, Y.-D.Wu and S.R.Moses J.Am.Chem.Soc. 108, 2754, (1986); K.N.Houk, M.N.Paddon-Row, N.G.Rondan, Y.-D.Wu, F.K.Brown, D.C.Spellmeyer, J.T.Metz, Y.Li and R.J.Loncharich Science 231, 1108 (1986).
6. E.Vedejs and C.K.McClure J.Am.Chem.Soc. 108, 1094 (1986).
7. S.Masamune, S.A.Ali, D.L.Smitman and D.S.Garvey Angew. Chem. Int. Ed. Engl. 19, 557 (1980).
8. C.H.Heathcok and S.H.Montgomery Tetrahedron Lett. 1001 (1985).
9. K.Mislow, R.E.O'Brien and H.Schaefer J.Am.Chem.Soc. 84, 1940 (1962); C.H.Heathcock, M.C.Pirrung, J.Lampe, C.T.Buse, S.D.Young J.Org.Chem 46,2290 (1981).
10. L.Banfi, A.Bernardi, L.Colombo, C.Gennari and C.Scolastico J.Org.Chem. 49, 3784 (1984).
11. W.C.Still and C.Gennari Tetrahedron Lett. 4405 (1983).
12. a) A.Bernardi, M.G.Beretta, L.Colombo, C.Gennari, G.Poli and C.Scolastico J.Org.Chem. 50, 4442 (1985); b) A.Bernardi, S.Cardani, L.Colombo, G.Poli, G.Schimperna, and C.Scolastico J.Org.Chem. 52, 888 (1987).
13. V.Van Rheenan, R.C.Kelly and D.Y.Cha Tetrahedron Lett. 1973 (1976).
14. The configuration at C-4 is already known while the relative C-2, C-3 configuration directly derives from the stereochemical outcome of the osmylation reaction. The C-3, C-4 relative configuration results from the ^{13}C-NMR spectra (diagnosed by the C-5 chemical shift 3-4 ppm shielded by a cis-hydroxy group at C-3) and from the $J_{3,4}$ in the ^{1}H-NMR spectra ($J_{3,4}$ trans > $J_{3,4}$ cis) as is well documented in lit. ref: S.Aburaki, N.Konishi and M.Kinoshita Bull.Chem.Soc.Jap. 48, 1254 (1975); C.Jaime, R.M.Ortuno and J.Font J.Org.Chem. 51, 3946 (1986); L.Banfi, S.Cardani, D.Potenza and C.Scolastico Tetrahedron 2317, (1987); C.H.Heathcock, D.S.Young, J.P.Hagen, M.C.Pirrung, C.T.Withe and D.VanDerveer J.Org.Chem. 45, 3846 (1980).
15. J.S.Burton, W.G.Overend and N.R.Williams J.Chem.Soc., 3433 (1965); R.J.Ferrier J.Chem.Soc. 3544 (1962).
16. M.Schroder Chem.Rev. 80, 187 (1980); K.B.Sharpless, A.Y.Teranishi and J.E.Backvall J.Am.Chem.Soc. 102, 4263 (1980); M.Schroder, E.C.Constable J.Chem.Soc.Chem.Comm. 734 (1982); C.P.Casey J.Chem.Soc.Chem.Comm. 126 (1983).
17. W.C.Still, M.Kahn and A.Mitra J.Org.Chem. 43, 2923 (1978).
18. R.J.Ferrier J.Chem.Soc.Perkin Trans I 3544 (1963).