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Chemoselective Reaction on a Hydroxy or Aldehyde Group Tethered with a Tri-substituted Ozonide: A Versatile Methodology for the Preparation of Terminally Differentiated Compounds from Cyclohexene

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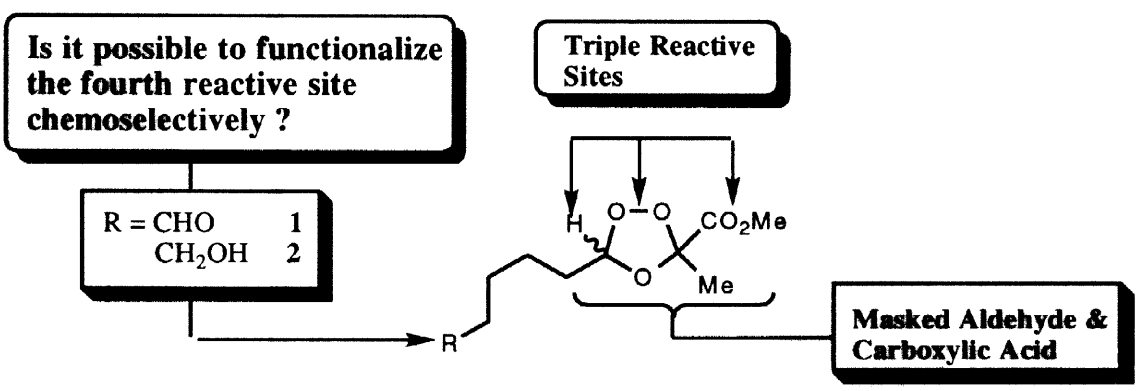
Abstract: Molecules containing a hydroxy or aldehyde group tethered with a tri-substituted ozonide moiety were prepared. We have demonstrated that the ozonide group is stable under certain Lewis acidic, free radical, and organometallic conditions. Therefore, chemoselective elaboration of the hydroxy or aldehyde group is possible under these conditions. These functional group transformations followed by the decomposition of the ozonide moiety provided an extremely convenient and versatile way to prepare terminally differentiated compounds from symmetric cyclohexene.

INTRODUCTION

Ozonides (1,2,4-trioxolane) have long been considered as unstable functional groups and are reduced or oxidized directly right after ozonolysis.[1] Although several ozonides have been isolated in pure form, studies on their stability and reactivity under different reaction conditions are rare.[2] The antimalarial activity of the plant extract artemisinin (Qinghaosu) is associated with the presence of 1,2,4-trioxane ring and a substantial effort has been devoted to develop new synthetic routes to these cyclic peroxides.[3] Reduction of the lactone on the artemisinin with $NaBH_4$ to give dihydroartemisinin (a lactol)[4] , with $NaBH_4$ in the presence of BF_3•Et_2O in

Fig. 1: The tri-substituted ozonides (**1-2**) contain four reactive sites.



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dry THF to give (+)-deoxoartemisinin[5] without affecting the peroxide bond. Recently, we reported that the ozonolytic cleavage of cycloalkenes in the presence of methyl pyruvate yielded the terminally differentiated compounds with an aldehyde at one end and the ozonide at the other end. The tri-substituted ozonide possessing three reactive centers as shown in Fig. 1 (*i.e.* the ozonide ring proton, peroxide, and CO_2Me) could be converted to different functional groups (*i.e.* aldehyde, carboxylic acid or enal) specifically by employing different reagents.[6] We also found that the aldedyde could be reduced to the alcohol, oxidized to carboxylic acid, and protected as a dimethyl acetal without affecting the ozonide moiety under mild conditions.[6] In our preliminary report, we have shown that the ozonides are also stable under some Lewis acidic, free radical and organometallic conditions where aldehyde reacted efficiently.[7] The structure shown in Fig. 1 possessed the fourth functional group (*i.e.* alcohol, aldehyde, or carboxylic acid). We are interested in investigating the scope of elaboration the fourth functional group chemoselectively in the presence of the ozonide. The decomposition of the ozonide after elaboration of the fourth functional group will make our methodology more useful. In other words, the success in these trials will broaden the synthetic utility of our methodology in preparing the terminally differentiated bifunctional compounds from symmetric cycloalkenes. In this report, we summarize the results of our work in this direction.

RESULTS AND DISCUSSION

The ozonolysis of cyclohexene in CH_2Cl_2 in the presence of 1.5 mol equiv. of methyl pyruvate at -78 °C afforded ozonide-aldehyde **1** as a mixture of two diastereomers in a ratio of 1:1 in 74% yield. The aldehyde-ozonide **1** obtained above was directly treated with a solution of $LiBH_4$ in THF to give the hydroxy-ozonide **2** in 56% yield. Their detailed preparation procedures were described in our previous reports.[6]

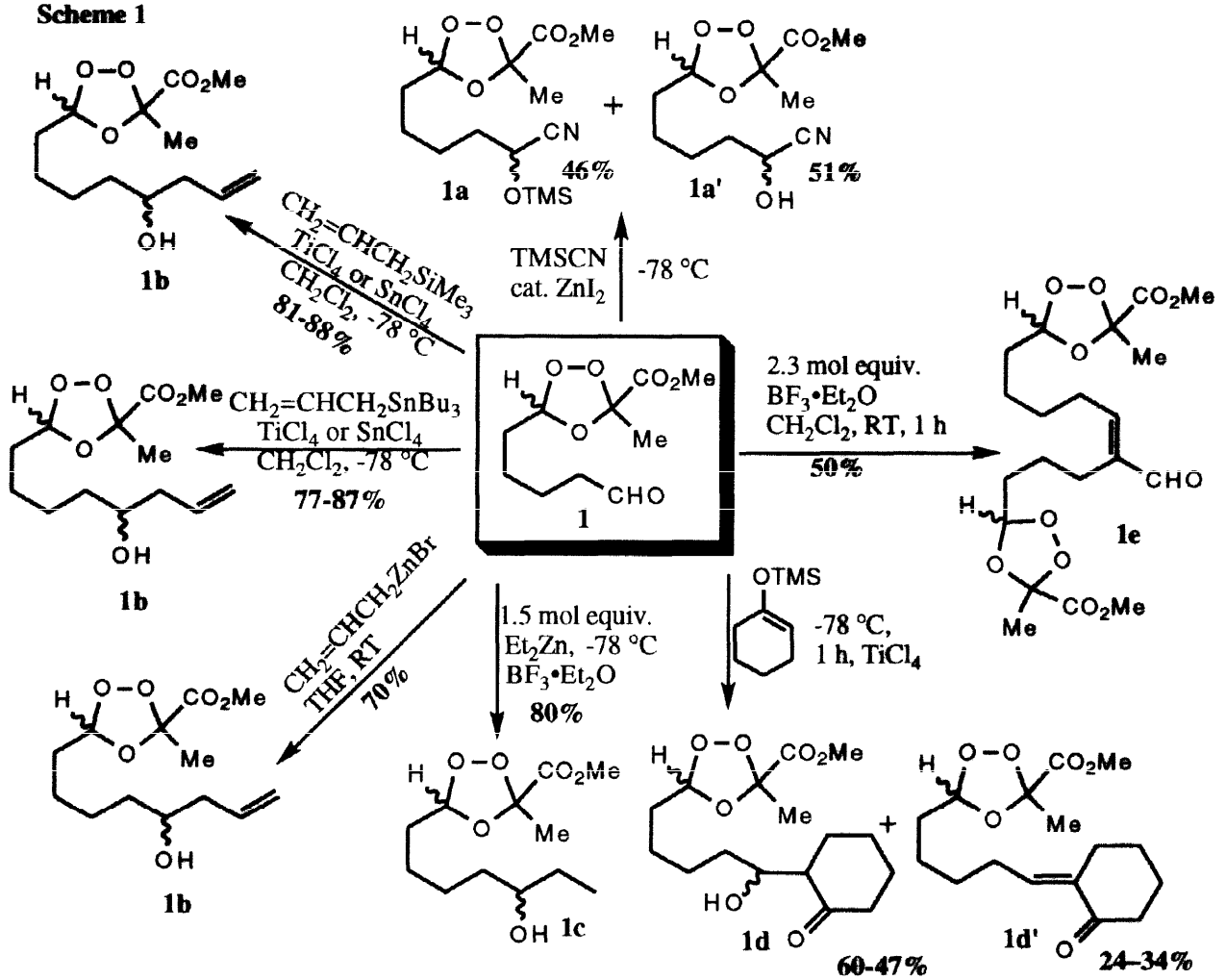
I. Chemoselective Elaboration of Aldehyde Tethered with Ozonide

Compound **1** reacted with trimethylsilyl cyanide in the presence of a catalytic amount of ZnI_2 to afford a mixture of trimethylsilyl cyanohydrin **1a** and cyanohydrin **1a'** within 0.2 h in excellent yields. The reaction mixtures should be submitted to column chromatography on silica gel directly to afford the pure products **1a** and **1a'**. If the reaction mixture was concentrated by rotary evaporator before column chromatography, the yields became poor. Presumably, the ZnI_2 might decompose the ozonide during the concentration. In the presence of $TiCl_4$ or $SnCl_4$, chemoselective allylation of the aldehyde moiety with allyltrimethylsilane[8] or allyltributylstannane[9] proceeded smoothly to give the homoallylic alcohol **1b** in high yields (Scheme 1). These results also indicated that the ozonide moiety is compatible with the stoichiometric amount of Lewis acids, such as $TiCl_4$ and $SnCl_4$ at -78 °C.

Ozonides were reported to react with the Grignard reagents to give carbinols.[10] However, when aldehyde-ozonide **1** was treated with an excess amount of a less reactive organozinc reagent such as allylzinc bromide at room temperature, the homoallylic alcohol-ozonide **1b** was formed chemoselectively in 70% yield. On the other hand, one mol equiv. of the $BF_3 \cdot Et_2O$[11] was required to promote the addition of Et_2Zn to aldehyde-ozonde **1** at -78 °C to give the secondary alcohol-ozonide **1c** in 80% yield. Apparently, the ozonide moiety was compatible with organozinc reagents (Scheme 1).

Since the ozonide moiety is compatible with stoichiometric amount of Lewis acids at -78 °C, the Mukaiyama-type aldol condensation between aldehyde **1** and 1-trimethylsiloxycyclohexene to form a mixture of

Scheme 1

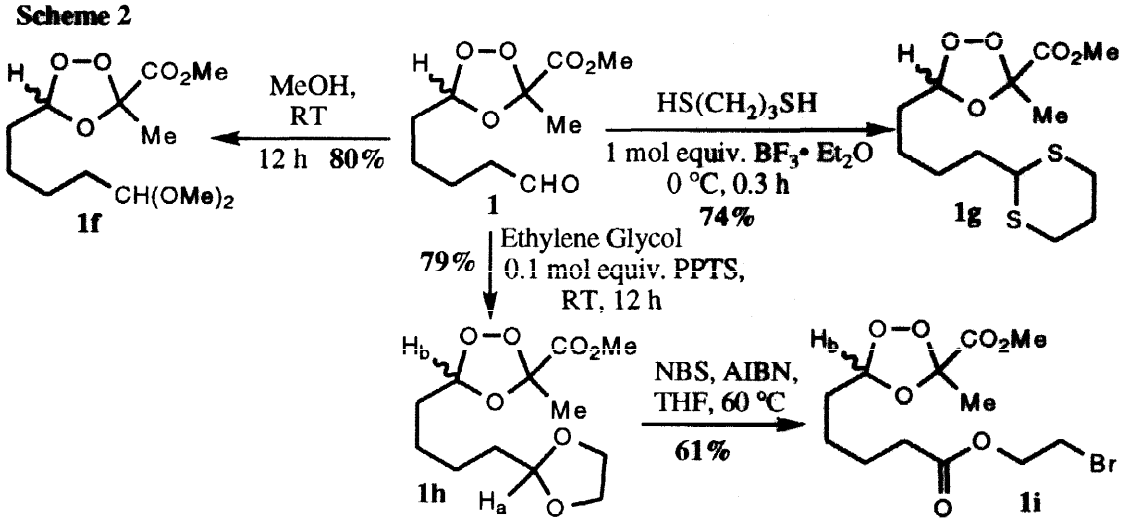


compounds **1d** and **1d'** is a logical extension.[12] β-Hydroxyketone **1d** was the predominant product as determined by TLC before workup. However, dehydration occurred rapidly during the aqueous workup. The double bond configuration of compound **1d'** was assumed to be the one shown in the Scheme 1 but was not assigned unambiguously. The BF_3•Et_2O-catalyzed self-aldol condensation of aldehyde **1** occurred chemoselectively at room temperature to give the corresponding conjugated enal **1e** in 50% yield. The proton of the aldehyde moiety in compound **1e** absorbed at δ 9.37 as a singlet and the vinylic proton absorbed at δ 6.48 as a triplet (J = 7.4 Hz) in its ^{1}H-NMR spectrum. Its double bond configuration was further determined by 2D-NOSY NMR technique (Scheme 1).

Dimethyl acetal-ozonide **1f** could be prepared from aldehyde **1** and methanol in 80% yield at room temperature without a catalyst. Aldehyde **1** reacted with 1,3-propanedithiol in the presence of 1 mol equiv. of BF_3•Et_2O to give 1,3-dithiane-ozonide **1g**, which could be isolated as a spectroscopically pure compound in 79% yield, however, it decomposed slowly on storage even in the freezer. Since methyl sulfide is a reducing agent to the ozonide,[1] the decomposition of compound **1g** on storage might be due to the the reduction of the ozonide by 1,3-dithiane moiety intra- or intermolecularly. Aldehyde **1** was treated with ethylene glycol in

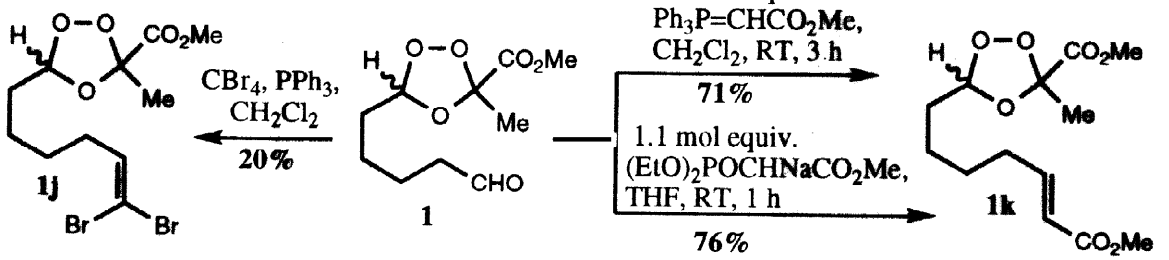
acetone in the presence of a catalytic amount of pyridinium *p*-toluenesulfonate (PPTS) to give 1,3-dioxolane **1h** in 79% yield. When a solution of 1,3-dioxolane **1h** in THF was treated with *N*-bromosuccinimide (NBS) in the presence of AIBN at 60 °C for 4 h,[13] the bromoethyl ester **1i** was formed in 61% yield. Under this reaction condition, H_a was much more labile than H_b on the 1,2,4-trioxolane of compound **1h**. In other words, it is possible to functionalize the cyclic acetal *via* a free radical process without breaking the ozonide ring in good yield (Scheme 2). To the best of our knowledge, this is the first example to demonstrate the stability of the ozonide moiety under free radical conditions.

Scheme 2

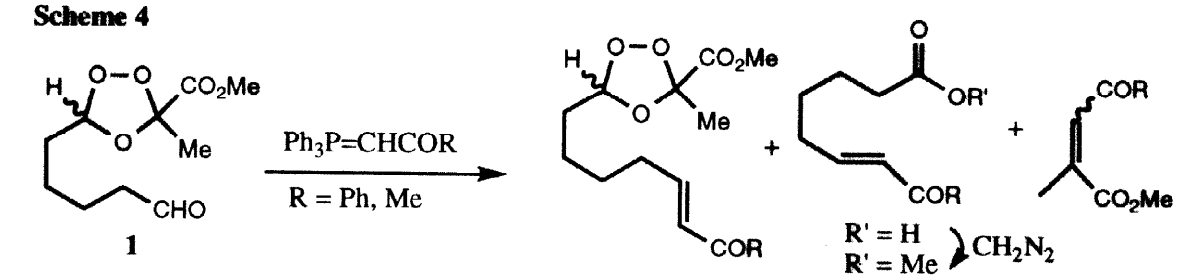


We have reported that mono-substituted ozonides could react with stable phosphonium ylides to form *trans*-α,β-unsaturated carbonyl compounds in high yields.[14] The first step of the mechanism probably involved the deprotonation of the ozonide ring protons by the stable phosphonium ylides.[14c,15] In other words, the phosphonium ylide could react with ozonide and aldehyde. It is interesting to compare the reactivity between aldehyde and ozonide in the same molecule, such as aldehyde-ozonide **1**, toward the phosphonium ylides. A mixture of CBr_4 (1 mol equiv.) and Ph_3P (2 mol equiv.) in CH_2Cl_2 was stirred at room temperature for 30 min. To the resulted mixture was added aldehyde-ozonide **1** to give the dibromomethylene **1j** in 20% yield. The reaction was quite clean as shown by TLC but the chemical yield was low. Presumably, the presence of $Ph_3P{\bullet}Br_2$[16] formed in the reaction mixture might decompose the ozonide moiety. The aldehyde-ozonide **1** could be transformed to α,β-unsaturated ester-ozonide **1k** *via* either Wittig or Wittig-Horner-Wadsworth reaction in 71% and 76% yields, respectively. When aldehyde-ozonide **1** reacted with 1.1 mol equiv. of $Ph_3P{=}CHCOPh$ in CH_2Cl_2 at room temperature, besides the desired enone-ozonide **1m** (60% yield), we also isolated 21% yield of the enone-acid **1n**, and 20% yield of enone **1o** (Scheme 4). The formation of compounds **1n** and **1o** was speculated as follows. The ozonide ring proton of the Wittig reaction product **1m** was deprotonated by $Ph_3P{=}CHCOPh$ followed by ring fragmentation to give both enone-acid **1n** and methyl pyruvate, which could subsequently react with $Ph_3P{=}CHCOPh$ to give enone **1o** in both *E*- and *Z*-forms (Pathway I, Fig. 2). We can not rule out the possibility of the pathway II (Fig. 2) where the decomposition of the ozonide **1** by phosphonium ylide occurred before Wittig reaction. The attempt to use the arsonium ylide[17] (*i.e.* $Ph_3As{=}CHCOPh$) in the same reaction in order to avoid the side products formation failed. When aldehyde-ozonide **1** reacted with 1.1 mol equiv. of $Ph_3P{=}CHCOMe$ in CH_2Cl_2 at room temperature for 6 h, the starting material cannot be consumed

Scheme 3

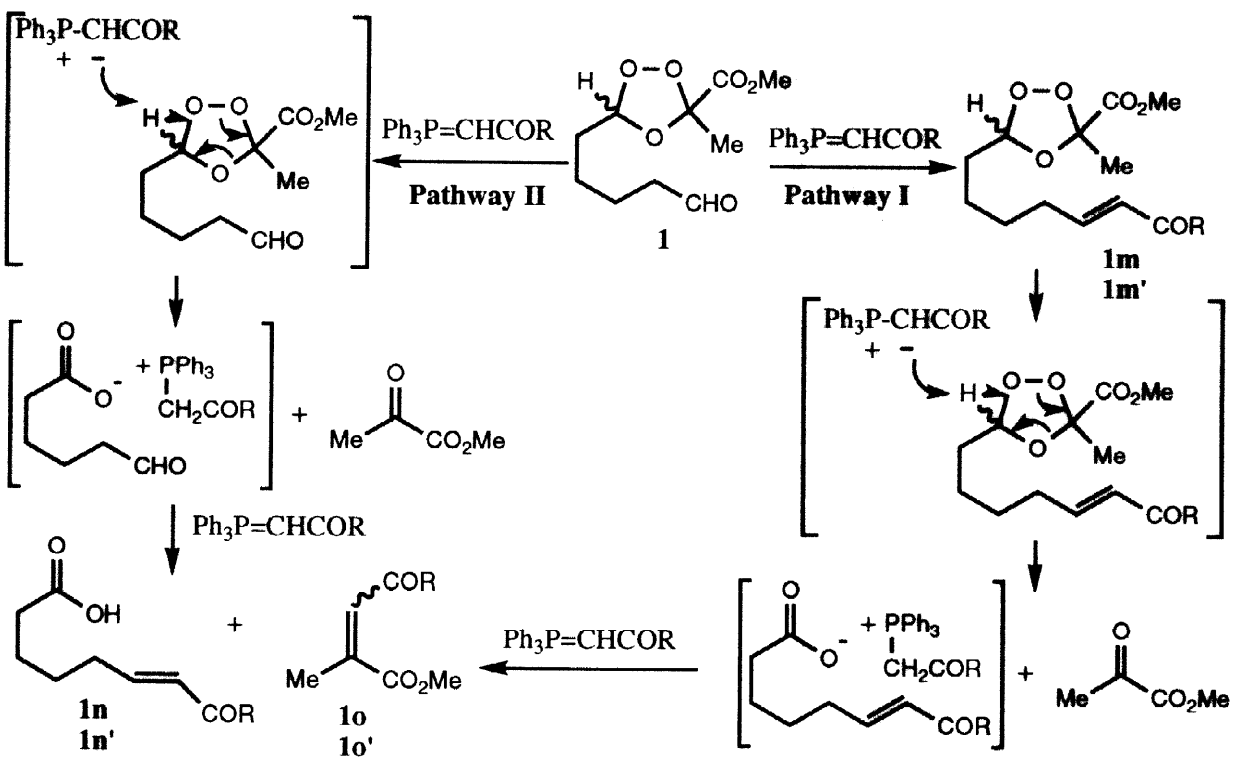


Scheme 4



1.1 mol equiv. Ph_3P=CHCOPh, CH_2Cl_2, RT, 3 h	*R = Ph; R' = Me*	**1m** 60%	**1n** 21%	**1o** 20%
2.3 mol equiv. Ph_3P=CHCOMe, CH_2Cl_2, RT, 3 h	*R = Ph; R' = Me*	**1m'** 22%	**1n'** 22%	**1o'** 57%

Fig. 2: The proposed mechanisms for the reaction of aldehyde-ozonide **1** with Ph_3P=CHCOR

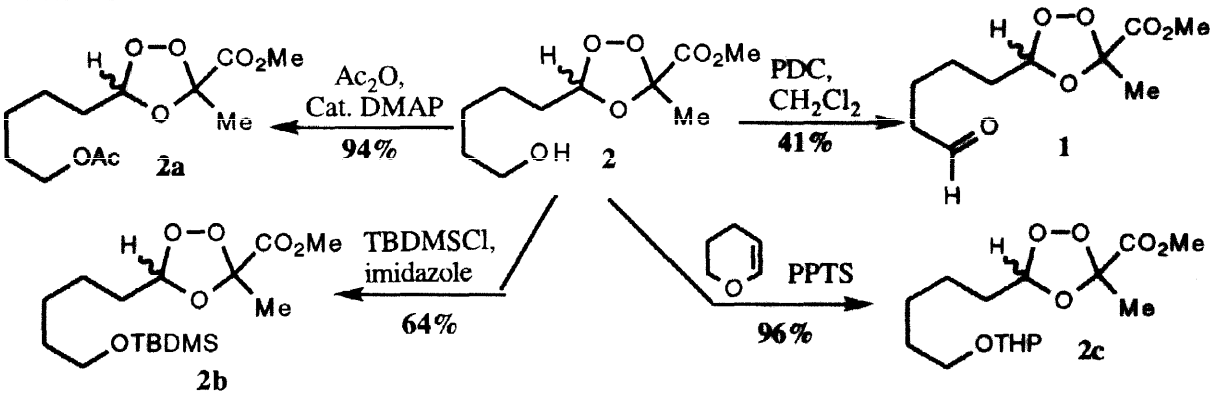


completely and another 1.2 mol equiv. of the ylide were needed to complete the reaction. Under this condition, we obtained 22% yield of enone-ozonide **1m'**, 22% yield of the enone-acid **1n'**, and 57% yield of enone **1o'** (Scheme 4). The double bond configuration assignment of compounds **1o'**[18] and **1o'**[19] were based on the literature reports. It is not clear why Ph_3P=CHCOR (R = Ph and Me) had greater tendency to decompose the ozonide ring of compound **1** than Ph_3P=$CHCO_2Me$ (cf. Schemes 3 and 4).

II. Chemoselective Functionalization of the Hydroxy Group Tethered with Ozonides

The reaction of hydroxy-ozonide **2** with Ac_2O in the presence of a catalytic amount of DMAP[20] afforded the corresponding acetate-ozonide **2a** in excellent yield. Compound **2** can also be protected as a *tert*-butyldimethylsilyl ether **2b**, and *O*-tetrahydropyran **2c** chemoselectively in good yields. It was possible to oxidize the hydroxy group in aldehyde **1** by pyridinium dichromate (PDC) albeit in modest yield (Scheme 5).

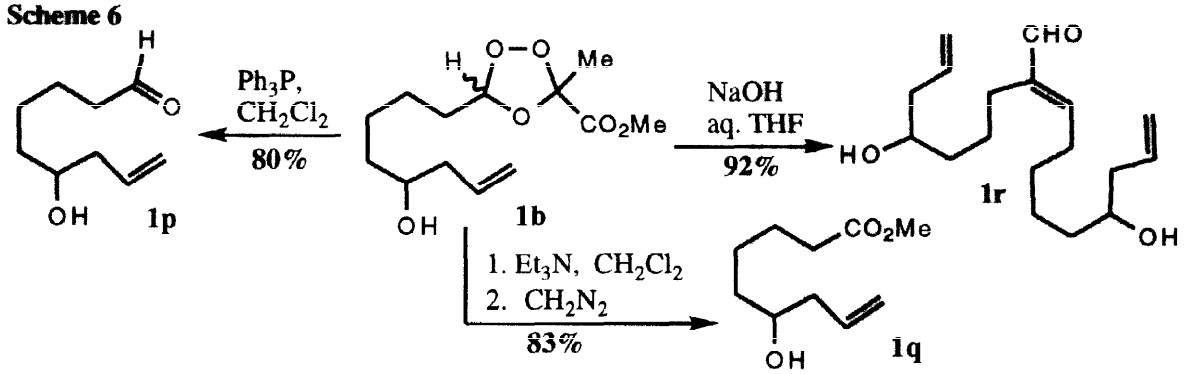
Scheme 5



III. Decomposition of the Ozonide Moiety after Elaboration of the Fourth Group

We have demonstrated that the chemoselective elaboration of aldehyde (or hydroxy) group tethered with ozonide was possible under a variety of reaction conditions. We have also demonstrated in our previous reports that the trisubstituted ozonide moiety with triple reactive sites are useful synthons of the carboxylic acid, aldehyde and enal.[6] In order to extend the usefulness of our methodology, we then used homoallylic alcohol-ozonide **1b** as an example and decomposed its ozonide ring by different reagents. Compound **1b** was treated with Ph_3P to give an aldehyde **1p** in 80% yield. Compound **1b** was reacted with Et_3N and the crude product was further treated with CH_2N_2 to give the corresponding methyl ester **1q** in 83% yield. The reaction of the ozonide **1b** with aqueous sodium hydroxide in THF produced the α,β-unsaturated aldehyde **1r** in 92% yield as

Scheme 6



a mixture of two diastereomers (Scheme 6). The *E* configuration of the double bond of compound **1r** was assumed to be the same as what we observed in our previous studies.[6] Therefore, the decomposition of the ozonide moiety after elaboration of the fourth group (Fig. 1) provided an extremely expedient entry to prepare the terminally differentiated compounds (*i. e.* **1p**, **1q** and **1r**) in only three steps from cyclohexene.

CONCLUSIONS

In this report, we have demonstrated that (1) it is possible to functionalize the aldehyde and hydroxy groups in the presence of the ozonide moiety under a variety of reaction conditions; (2) the decomposition of the ozonide group after the fourth group elaboration provided an extremely convenient and versatile way to prepare terminally differentiated compounds from symmetric cyclohexene. These products (**1p**, **1q** and **1r**) possessed three to six different functional groups in the same molecule. Since the preparation of the aldehyde and hydroxy tethered with ozonides from the other cycloalkenes are possible,[6b] the application of the present chemistry to them should be a logical extension.

EXPERIMENTAL

All reactions were carried out under nitrogen. Unless otherwise noted, materials were obtained from commercial suppliers and used without further purification. Ozone was prepared with a Fisher ozone generator (Model 501). Melting points were determined by using a Yanaco micro melting point apparatus and were uncorrected. The ^{1}H and ^{13}C-NMR spectra were recorded on a Bruker AC 200 spectrometer, and chemical shifts were given in ppm downfield from tetramethylsilane (TMS). IR spectra were taken with a Perkin Elmer 882 spectrophotometer and only noteworthy absorptions were listed. Mass spectra were measured on a VG 70-250S mass spectrometer by electronic impact at 70 eV (unless otherwise indicated). The general workup procedure was described as follows. The extracts were washed with water and brine. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product.

5-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)pentanal (1): A two-necked flask was fitted with a glass tube to admit ozone, a $CaCl_2$ drying tube and a magnetic stirring bar and was charged with cyclohexene (160.1 mg, 1.95 mmol), methyl pyruvate (299.0 mg, 2.93 mmol) and CH_2Cl_2 (10 mL). The flask is cooled to -78 °C and ozone is bubbled through the solution. When the solution turned blue, ozone addition was stopped. Nitrogen was passed through the solution until the blue color was discharged. Removal of solvent afforded the crude product. The silica gel column chromatography by elution with EtOAc/hexane to give the tri-substituted ozonide **1** (335.1 mg, 2.93 mmol; 74% yield) as a 1 : 1 mixture of two diastereomers. TLC (EtOAc/Hexane = 1/1) R_f = 0.40; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.66 (s, 3H, -C<u>H</u>$_3$), 1.42-1.81 (m, 6H), 2.48 (t, *J* = 6.9 Hz, 2H, -C<u>H</u>$_2$-CHO), 3.80 (s, 3H, -CO$_2$C<u>H</u>$_3$), 5.24 (t, *J* = 4.8 Hz, 0.5H, -OC<u>H</u>RO-), 5.44 (t, *J* = 5.1 Hz, 0.5H, -OC<u>H</u>RO-), 9.76 (s, 1H, <u>H</u>C=O); ^{13}C-NMR ($CDCl_3$) δ 18.1 (<u>C</u>H$_3$), 18.8, 21.1 (2°), 22.7 (2°), 29.0 (R<u>C</u>H$_2$(CH$_2$)$_3$CHO), 32.1 (HCO<u>C</u>H$_2$), 52.3 (-CO$_2$<u>C</u>H$_3$), 52.4, 103.7 (-O<u>C</u>CH$_3$RO-), 104.8 (-O<u>C</u>HRO-), 168.0 (<u>C</u>OOCH$_3$), 168.5, 201.6 (H<u>C</u>OR); IR (CH_2Cl_2) (ν, cm $^{-1}$): 2958 (C-H), 1753 (C=O), 1433, 1374, 1282, 1250.

1-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-5-cyano-5-trimethylsiloxypentane (1a) and 1-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-5-cyano-5-hydroxypentane (1a'): To a solution of aldehyde-ozonide **1** (157.1 mg, 0.68 mmol) in 3 mL of CH_2Cl_2 was added trimethylsilyl cyanide (140.8 mg, 1.42 mmol) and zinc iodide (22.0 mg, 0.07 mmol) at room temperature. The color of solution turned red gradually and the reaction completed in 20 min. The reaction mixture was poured on silica gel column chromatography and eluted with EtOAc/hexane to give trimethylsilyl cyanohydrin **1a** (89.4 mg, 0.35 mmol; 51% yield) and cyanohydrin **1a'** (98.0 mg, 0.20 mmol; 46% yield). Compound **1a**: TLC (EtOAc/Hexane = 1/3) R_f = 0.49; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 0.21 (s, 9H, -OSi($C\underline{H}_3$)$_3$), 1.49-1.81 (m, 8H), 1.68 (s, 3H, -$C\underline{H}_3$), 3.81 (s, 3H, -$CO_2C\underline{H}_3$), 4.40 (t, *J* = 6.7 Hz, 1H, -OC<u>H</u>CNO-), 5.24 (t, *J* = 4.8 Hz, 0.5H, -OC<u>H</u>RO-), 5.45 (t, *J* = 5.1 Hz, 0.5H, ORC<u>H</u>O-); ^{13}C-NMR ($CDCl_3$) δ -0.48 (-Si($C\underline{H}_3$)$_3$), 18.6 ($\underline{C}H_3$), 19.3, 23.0 (2°), 24.2, 29.5 (2°), 32.6 (2°), 35.9 (2°), 52.9 (-$CO_2\underline{C}H_3$), 61.2 (H<u>C</u>-CN), 104.2 (-O<u>C</u>CH$_3$CO$_2$CH$_3$), 119.8 (-CN), 169.1 (-<u>C</u>O$_2$CH$_3$); IR (CH_2Cl_2) (ν, cm^{-1}): 2957 (C-H), 1753 (C=O), 1445, 1374, 1344, 1286, 1189, 846; MS (m/z) (60 eV, rel. intensity): 301 (M^+-16, 2), 286 (28), 259 (9), 242 (1), 231 (2), 201 (2), 196 (6), 169 (42), 147 (80), 129 (14), 113 (2), 103 (19), 84 (20), 75 (100), 73 (99). Compound **1a'**: Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.49-2.01 (m, 8H), 1.68 (s, 3H, -$C\underline{H}_3$), 3.37 (br, 1H, -O<u>H</u>), 3.82 (s, 3H, -$CO_2C\underline{H}_3$), 4.50 (t, *J* = 6.1 Hz, 1H, -OC<u>H</u>CNO-), 5.25 (t, *J* = 4.7 Hz, 0.6H, -OC<u>H</u>RO-), 5.46 (t, *J* = 5.1 Hz, 0.4H, ORC<u>H</u>O-); ^{13}C-NMR ($CDCl_3$) δ 18.6 ($\underline{C}H_3$), 19.2, 22.9 (2°), 24.1, 24.2, 29.3 (2°), 32.6 (2°), 34.7 (2°), 53.0 (-$CO_2\underline{C}H_3$), 60.8 (H<u>C</u>-CN), 104.2 (-O<u>C</u>CH$_3$COOCH$_3$), 105.2 (O-<u>C</u>HR-O), 119.9 (-CN), 168.6 (-<u>C</u>OOCH$_3$), 169.4; IR (CH_2Cl_2) (ν, cm^{-1}): 3550 (-OH), 2956 (C-H), 1754 (C=O), 1444, 1375, 1283, 1191.

1-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-5-hydoxy-7-octene (1b): There are several different conditions (**A-E**) to prepare compound **1b** as a mixture of diastereomers.

(A) Reaction with Allyltrimethylsilane Catalyzed by $TiCl_4$: To a solution of aldehyde-ozonide **1** (201.6 mg, 0.87 mmol) in 5 mL of CH_2Cl_2 was added $TiCl_4$ (1.0 M in CH_2Cl_2, 0.5 mL, 0.5 mmol) and allyltrimethylsilane (108.9 mg, 0.96 mmol) subsequently at -78 °C. The reaction was quenched with water at -78 °C after 20 min and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane (1 : 4) to give the desired product **1b** (210.1 mg, 0.77 mmol, 88%).

(B) Reaction with Allyltrimethylsilane Catalyzed by $SnCl_4$: To a solution of aldehyde-ozonide **1** (210.9 mg, 0.91 mmol) in 5 mL of CH_2Cl_2 was added $SnCl_4$ (1.0 M in CH_2Cl_2, 0.9 mL, 0.9 mmol) and allyltrimethylsilane (113.9 mg, 1.00 mmol) subsequently at -78 °C. The reaction was quenched with water at -78 °C after 15 min and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1b** (201.7 mg, 0.74 mmol, 81%).

(C) Reaction with Allyltributyltin Catalyzed by $TiCl_4$: To a solution of aldehyde-ozonide **1** (211.9 mg, 0.91 mmol) in 5 mL of CH_2Cl_2 was added $TiCl_4$ (1.0 M in CH_2Cl_2, 0.5 mL, 0.5 mmol) and allyltributyltin (332.5 mg, 1.00 mmol) subsequently at -78 °C. The reaction was quenched with water at -78 °C after 30 min and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1b** (217.5 mg, 0.79 mmol, 77%).

(D) Reaction with Allyltributyltin Catalyzed by $SnCl_4$: To a solution of aldehyde-ozonide **1** (201.6 mg, 0.87 mmol) in 5 mL of CH_2Cl_2 was added $SnCl_4$ (1.0 M in CH_2Cl_2, 0.9 mL, 0.9 mmol) and allyltributyltin (316.5 mg, 0.96 mmol) subsequently at -78 °C. The reaction was quenched with water at -78 °C after 30 min and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1b** (184.0 mg, 0.67 mmol, 77%).

(E) Reaction with Allylzinc Bromide: To a solution of allyl bromide (223.3 mg, 1.85 mmol) in 4 mL of THF was added zinc powder (120 mg, 1.85 mmol) at room temperature and stirred for 30 min to form the the solution of allylzinc bromide in THF. To a solution of aldehyde-ozonide **1** (206.1 mg, 0.89 mmol) in 5 mL of THF was added allylzinc bromide in THF at room temperature. The reaction was quenched with water after 20 min and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1b** (174.0 mg, 0.62 mmol, 70%).

Compound **1b**: TLC (EtOAc/Hexane=1/3) R_f = 0.25; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.47-1.83 (m, 6H), 1.67 (s, 3H, -C<u>H</u>$_3$), 2.11-2.23 (m, 4H, RCH$_2$C(OH)HC<u>H</u>$_2$CH=CH$_2$), 3.65 (brs, CH$_2$C(OH)<u>H</u>CH$_2$), 3.81 (s, 3H, -CO$_2$C<u>H</u>$_3$), 5.10-5.20 (m, 2H, -C=C<u>H</u>$_2$), 5.24 (t, *J* = 4.4 Hz, 0.5H, -OC<u>H</u>RO-), 5.44 (t, *J* = 4.8 Hz, 0.5H, -OC<u>H</u>RO-), 5.70-5.90 (m, 1H, -C<u>H</u>=CH$_2$); ^{13}C-NMR ($CDCl_3$) δ 18.5 (<u>C</u>H$_3$), 19.3, 23.5 (2°), 25.1 (2°), 29.5 (2°), 32.5 (2°), 36.2 (2°), 41.7 (2°), 52.7 (-CO$_2$<u>C</u>H$_3$), 70.2 (CH$_2$<u>C</u>H(OH)CH$_2$), 103.9 (-O<u>C</u>CH$_3$CO$_2$CH$_3$), 105.3 (O-<u>C</u>HR-O), 117.7 (R<u>C</u>H=CH$_2$), 134.6 (R-<u>C</u>H=CH$_2$), 168.4 (-<u>C</u>O$_2$CH$_3$), 169.0; IR (CH_2Cl_2) (ν, cm^{-1}): 3650-3200 (-OH), 2936 (C-H), 1752 (C=O), 1638, 1433, 1372, 1242.

1-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-5-hydroxyheptane (1c): To a solution of aldehyde-ozonide **1** (306.1 mg, 1.32 mmol) in 6 mL of CH_2Cl_2 was added diethylzinc (1.0 M in hexane, 2.0 mL, 2.0 mmol) and BF_3•Et_2O (281.0 mg, 1.98 mmol) at -78 °C. After 2 h, the reaction mixture was quenched with saturated aqueous NH_4Cl at -78 °C and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1c** as a mixture of diastereomers (276.5 mg, 1.06 mmol, 80%). TLC (EtOAc/Hexane = 1/3) R_f = 0.15; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 0.94 (t, *J* = 7.3 Hz, 3H, RCHOHCH$_2$C<u>H</u>$_3$), 1.26-1.80 (m, 10H), 1.68 (s, 3H, -C<u>H</u>$_3$), 3.52 (br, RCHO<u>H</u>CH$_2$CH$_3$), 3.81 (s, 3H, -CO$_2$C<u>H</u>$_3$), 5.24 (t, *J* = 4.9 Hz, 0.6H, -OC<u>H</u>RO-), 5.44 (t, *J* = 5.3 Hz, 0.4H, ROC<u>H</u>O-); ^{13}C-NMR ($CDCl_3$) δ 9.79 (<u>C</u>H$_3$), 18.7 (-<u>C</u>H$_3$), 19.5, 23.8 (2°), 25.3 (2°), 25.4, 29.7 (2°), 30.1, 32.7 (2°), 36.5 (2°), 52.8 (-CO$_2$<u>C</u>H$_3$), 52.9, 73.0 (R'<u>C</u>HOHR), 104.1 (-O<u>C</u>CH$_3$CO$_2$CH$_3$), 105.5 (-O-<u>C</u>HR-O-), 105.6, 169.1 (-<u>C</u>O$_2$CH$_3$); IR (CH_2Cl_2) (ν, cm^{-1}): 3650-3200 (-OH), 2936 (C-H), 1754 (C=O), 1434, 1374, 1254, 1190.

5-[5-Hydroxy-5-(2-oxocyclohexyl)pentyl]-3-methyl-3-methoxycarbonyl-[1,2,4]trioxolane (1d) and 5-[5-(2-Oxocyclohexylidene)pentyl]-3-methyl-3-methoxycarbonyl[1,2,4]trioxolane (1d'): To a mixture of aldehyde-ozonide **1** (204.5 mg, 0.88 mmol) and 1-trimethylsiloxy-1-cyclohexene (164.8 mg, 0.97 mmol) in 5 mL of CH_2Cl_2 was added $TiCl_4$ (1M in CH_2Cl_2, 1.32 mL) at -78 °C. After 1 h, the reaction mixture was quenched with H_2O at -78 °C and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1d** (174.8 mg, 0.53 mmol; 60% yield) and product **1d'** (66.0 mg, 0.21 mmol; 24% yield). Compound **1d**: TLC (EtOAc/Hexane = 1/3) R_f = 0.15; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.26-2.08

(m, 14H), 1.71 (s, 3H, -C<u>H</u>$_3$), 1.72, 2.31-2.37 (m, 3H, -C<u>H</u>$_2$COC<u>H</u>R), 3.73 (br, 1H, -OH), 3.80 (s, 3H, -OC<u>H</u>$_3$), 5.23 (t, J = 4.6 Hz, 0.5 Hz, -OC<u>H</u>RO-), 5.43 (t, J = 5.1 Hz, 0.5H, -OC<u>H</u>RO-); ^{13}C-NMR (CDCl$_3$) δ 18.4 (<u>C</u>H$_3$), 19.2, 23.4, 23.5, 24.6 (2°), 24.7, 25.7 (2°), 26.3 (2°), 27.4 (2°), 27.5 (2°), 29.5 (2°), 30.3 (2°), 32.5 (2°), 33.0, 33.1, 42.3 (-<u>C</u>H$_2$CO), 42.5, 52.5 (-CO$_2$<u>C</u>H$_3$), 52.6, 54.8, 55.6, 68.6 (R<u>C</u>H-OH), 71.0, 103.9 (-O<u>C</u>CH$_3$CO$_2$CH$_3$), 105.2 (O-<u>C</u>HR-O), 105.3, 168.3 (-<u>C</u>O$_2$CH$_3$), 168.9, 214.3 (C=O), 215.2; IR (CH$_2$Cl$_2$) (ν, cm $^{-1}$): 3650-3590 (-OH), 2946 (C-H), 1754 (C=O), 1432, 1375, 1285, 1191. **Compound 1d'**: TLC (EtOAc/Hexane = 1/3) R_f = 0.37; Colorless oil; ^{1}H-NMR (CDCl$_3$) δ 1.29-1.88 (m, 10H), 1.77 (s, 3H, -C<u>H</u>$_3$), 2.10 (t, J = 7.0 Hz, 2H, -C<u>H</u>$_2$COR), 2.40-2.51 (m, 4H), 3.81 (s, 3H, -OC<u>H</u>$_3$), 3.82, 5.23 (t, J = 4.8 Hz, 0.4 Hz, -OC<u>H</u>RO-), 5.44 (t, J = 4.6 Hz, 0.6H, -OC<u>H</u>RO-), 6.59 (t, J = 7.5 Hz, 1H, C=C<u>H</u>R); ^{13}C-NMR (CDCl$_3$) δ 18.8 (<u>C</u>H$_3$), 19.4, 23.3 (2°), 23.5 (2°), 26.7 (2°), 27.4 (2°), 28.1 (2°), 28.2, 29.6 (2°), 32.6 (2°), 40.1 (-<u>C</u>H$_2$CO), 43.6, 52.8 (-CO$_2$<u>C</u>H$_3$), 53.0, 104.2 (-O<u>C</u>CH$_3$CO$_2$CH$_3$), 105.4 (O-<u>C</u>HR-O), 136.5 (-<u>C</u>=CH-), 138.6 (-C=<u>C</u>H-), 168.5 (<u>C</u>O$_2$CH$_3$), 169.1, 201.0 (C=O); IR (CH$_2$Cl$_2$) (ν, cm $^{-1}$): 2952 (C-H), 1729 (C=O), 1455, 1372, 1238, 1191.

1,9-Bis-(5-methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-4-formyl-4(*E*)-nonane (1e): To a mixture of aldehyde-ozonide **1** (210.9 mg, 0.88 mmol) in 5 mL of CH_2Cl_2 was added BF_3•Et_2O (0.25 mL, 2.03 mmol) at room temperature and stirred at this temperature for 1 h. The reaction mixture was submitted to column chromatography on silica gel and eluted with EtOAc/hexane to give the desired product **1e** (201.6 mg, 0.44 mmol; 50% yield). TLC (EtOAc/Hexane = 1/3) R_f = 0.21; Colorless oil; ^{1}H-NMR (CDCl$_3$) δ 1.26-2.13 (m, 10H), 1.67 (s, 3H, -C<u>H</u>$_3$), 1.68 (s, 3H, -C<u>H</u>$_3$), 2.24-2.43 (br, 4H, -C<u>H</u>$_2$CH=C(CHO)HC<u>H</u>$_2$-), 3.78 (s, 3H, -OC<u>H</u>$_3$), 3.81 (s, 3H, -OC<u>H</u>$_3$), 5.23 (t, J = 4.9 Hz, 0.5 Hz, -OC<u>H</u>RO-), 5.26 (t, J = 4.8 Hz, 0.5H, -OC<u>H</u>RO-), 5.44 (t, J = 5.1 Hz, 0.5H, -OC<u>H</u>RO-), 5.46 (t, J = 5.0 Hz, 0.5H, -OC<u>H</u>RO-), 6.48 (t, J = 7.4 Hz, 1H, -C<u>H</u>=C(CHO)R), 9.37 (s, 1H, C<u>H</u>O); ^{13}C-NMR (CDCl$_3$) δ 18.6 (<u>C</u>H$_3$), 19.3, 22.7 (2°), 23.4, 28.2 (2°), 28.7, 29.6 (2°), 32.5 (2°), 52.9 (-CO$_2$<u>C</u>H$_3$), 104.1 (-O<u>C</u>CH$_3$CO$_2$CH$_3$), 105.2 (O-<u>C</u>HR-O), 143.1 (CH=<u>C</u>RCHO), 154.8 (H<u>C</u>=CRCHO), 168.5 (-<u>C</u>O$_2$CH$_3$), 194.8 (C=O); IR (CH$_2$Cl$_2$) (ν, cm $^{-1}$): 2939 (C-H), 1751 (C=O), 1433, 1373, 1252, 1188.

5-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)pentanal dimethyl acetal (1f): To a mixture of aldehyde-ozonide **1** (210.9 mg, 0.88 mmol) in 3 mL of CH_2Cl_2 was added 3 mL of MeOH at room temperature and stirred at this temperature for 10 h. The reaction mixture was concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1f** (195.7 mg, 0.70 mmol; 80% yield). TLC (EtOAc/Hexane = 1/1) R_f = 0.66; Colorless oil; ^{1}H-NMR (CDCl$_3$) δ 1.38-1.83 (m, 8H), 1.67 (s, 3H, -C<u>H</u>$_3$), 3.31 (s, 6H, RCH(O<u>C</u>H$_3$)$_2$), 3.81 (s, 3H, -CO$_2$<u>C</u>H$_3$), 4.35 (t, J = 5.5 Hz, 1H, -R<u>C</u>H(OCH$_3$)$_2$-), 5.24 (t, J = 4.9 Hz, 0.6H, -OC<u>H</u>RO-), 5.44 (t, J = 5.2 Hz, 0.4H, -OC<u>H</u>RO-); ^{13}C-NMR (CDCl$_3$) δ 18.7 (<u>C</u>H$_3$), 23.6 (2°), 24.3 (2°), 27.9 (2°), 32.2 (2°), 52.7 (-CO$_2$<u>C</u>H$_3$), 52.8, 104.3 (-O<u>C</u>CH$_3$(CO$_2$CH$_3$)O-), 104.3 (R<u>C</u>H(OCH$_3$)$_2$), 105.4 (-O-CHR-O), 169.1 (<u>C</u>O$_2$CH$_3$); IR (CH$_2$Cl$_2$) (ν, cm $^{-1}$): 2954 (C-H), 1753 (C=O), 1435, 1374, 1287, 1192, 1137.

5-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)pentanal 1,3-dithiane (1g): To a solution of aldehyde-ozonide **1** (200.7 mg, 0.87 mmol) in 5 mL of CH_2Cl_2 was added 1,3-propanedithiol (102.8 mg, 0.95 mmol) and BF_3•Et_2O (0.1 mL, 0.87 mmol) at 0 °C and stirred at this temperature for 20 min. The reaction mixture was submitted to column chromatography on silica gel and eluted with EtOAc/hexane to give the desired

product **1g** (206.1 mg, 0.64 mmol; 74% yield). TLC (EtOAc/Hexane = 1/1) R_f = 0.56; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.43-1.87 (m, 8H), 1.73 (s, 3H, -C<u>H</u>$_3$), 2.77-2.89 (m, 6H, S-(C<u>H</u>$_2$)$_3$S), 3.81 (s, 3H, -$CO_2C\underline{H}_3$), 4.04 (t, J = 6.5 Hz, 1H, -SC<u>H</u>S-), 5.24 (t, J = 4.9 Hz, 0.5H, -OC<u>H</u>RO-), 5.44 (t, J = 5.1 Hz, 0.5H, -OC<u>H</u>RO-); ^{13}C-NMR ($CDCl_3$) δ 18.4 (<u>C</u>H$_3$), 19.1, 23.0 (2°), 25.7 (2°), 25.9 (2 °, -S<u>C</u>H$_2$-), 26.0, 29.3 (2°), 30.1 (2°), 32.3 (2°), 34.8 (2°), 46.9 (-S<u>C</u>HS-), 52.6 (-$CO_2\underline{C}H_3$), 103.8 (R<u>C</u>H(OCH$_3$)$_2$), 105.0 (-O<u>C</u>CH$_3$(CO$_2$CH$_3$)O-), 105.1, 168.2 (<u>C</u>O$_2$CH$_3$), 168.8; IR (CH_2Cl_2) (ν, cm^{-1}): 2954 (C-H), 1753 (C=O), 1422, 1374, 1254, 1132; MS (m/z) (60 eV, rel. intensity): 264 (M$^+$-59, 11), 234 (6), 204 (M$^+$-119), 145 (7), 129 (3), 121 (17), 119 (100), 106 (17), 98 (12), 91 (5), 85 (15), 74 (19), 67 (8), 59 (6).

5-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)pentanal 1,3-dioxolane (1h): To a solution of aldehyde-ozonide **1** (162.1 mg, 0.70 mmol) in 2 mL of ethylene glycol was added pyridinium *p*-toluenesulfonate (17.5 mg, 0.07 mmol) at room temperature and stirred at this temperature for 12 h. The reaction mixture was submitted to column chromatography on silica gel and eluted with EtOAc/hexane to give the desired product **1h** (104.6 mg, 0.40 mmol; 57% yield). TLC (EtOAc/Hexane = 1/3) R_f = 0.33; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.43-1.82 (m, 8H), 1.65 (s, 3H, -C<u>H</u>$_3$), 3.81 (s, 3H, -$CO_2C\underline{H}_3$), 3.83-4.00 (m, 4H, -OC<u>H</u>$_2$C<u>H</u>$_2$O-), 4.84 (t, J = 4.5 Hz, 1H, -OC<u>H</u>RO-), 5.24 (t, J = 4.9 Hz, 0.7H, -OC<u>H</u>RO-), 5.24 (t, J = 5.2 Hz, 0.3H, -OC<u>H</u>RO-); ^{13}C-NMR ($CDCl_3$) δ 18.7 (<u>C</u>H$_3$), 19.4, 23.6 (2°), 23.7, 32.7 (2°), 33.5 (2°), 52.8 (-$CO_2\underline{C}H_3$), 64.8 (-O<u>C</u>H$_2$<u>C</u>H$_2$O-), 104.3 (-O<u>C</u>HROO-), 105.4 (-O<u>C</u>CH$_3$(CO$_2$CH$_3$)O-), 169.1 (<u>C</u>O$_2$CH$_3$), 168.8; IR (CH_2Cl_2) (ν, cm^{-1}): 2956 (C-H), 1754 (C=O), 1434, 1397, 1374, 1254, 1189; MS (m/z) (60 eV, rel. intensity): 276 (M$^+$, 5), 275 (M$^+$-1, 34), 217 (M$^+$-59, 4), 200 (8), 191 (5), 157 (78), 141 (6), 114 (8), 99 (4), 87 (28), 73 (100), 59 (6), 43 (17).

2-Bromoethyl 5-(5-methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)pentanoate (1i): A solution of 1,3-dioxolane-ozonide **1** (286.3 mg, 1.0 mmol) and 2,2'-azobisisobutyronitrile (AIBN) (16.4 mg, 0.1 mmol) in 5 mL of THF was heated up to 60 °C for 3 h. The reaction mixture was concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1i** as a mixture of diastereomers (216.7 mg, 0.61 mmol; 61% yield); Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.43-1.89 (m, 7H), 2.40 (t, J = 3.4 Hz, 2H, -C<u>H</u>$_2$COO-), 3.52 (t, J = 6.1 Hz, 2H, -COOC<u>H</u>$_2$CH$_2$Br), 3.81 (s, 3H, -$CO_2C\underline{H}_3$), 4.39 (t, J = 6.1 Hz, 2H, -COOCH$_2$C<u>H</u>$_2$Br), 5.24 (t, J = 4.9 Hz, 0.8H, -OC<u>H</u>RO-), 5.42 (t, J = 4.9 Hz, 0.2H, -OC<u>H</u>RO-); ^{13}C-NMR ($CDCl_3$) δ 18.6 (<u>C</u>H$_3$), <u>19.3</u>, 23.13, 24.46, <u>25.06</u>, 28.68, 29.38, <u>32.46</u>, 33.64, 52.80 (-$CO_2\underline{C}H_3$), 63.60, 104.15 (-O<u>C</u>HROO-), 105.17 (-O<u>C</u>CH$_3$(CO$_2$CH$_3$)O-), 169.03 (<u>C</u>O$_2$CH$_3$), 172.67; IR (CH_2Cl_2) (ν, cm^{-1}): 2959 (C-H), 1737 (C=O), 1438, 1375, 1255, 1188; MS (m/z) (60 eV, rel. intensity): 356 (M$^+$, 7, containing ^{81}Br), 354 (M$^+$, 8, containing ^{79}Br), 195 (6), 193 (7), 181 (M$^+$-(CH$_2$)$_2$CO$_2$(CH$_2$)$_2$^{81}Br, 10), 179 (M$^+$-(CH$_2$)$_2$CO$_2$(CH$_2$)$_2$^{79}Br, 11), 109 (M$^+$-(CH$_2$)$_2$^{81}Br, 94), 107 (M$^+$-CH$_2$CH$_2$^{79}Br, 100), 83 (50), 67 (52). The underline means those peaks from minor diastereomer.

6-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-1,1-dibromo-1-hexene (1j): A solution of Ph_3P (340.4 mg, 1.30 mmol) and CBr_4 (215.0 mg, 0.65 mmol) in 4 mL of CH_2Cl_2 was stirred at room temperature for 0.5 h. To the resulted solution was added aldehyde-ozonide **1** (150.7 mg, 0.65 mmol) in 2 mL of CH_2Cl_2 at room temperature and stirred at this temperature for 0.5 h. The reaction mixture was concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1j** (50.7 mg, 0.13 mmol; 20% yield). TLC (EtOAc/Hexane = 1/3) R_f = 0.59; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.48-

1.83 (m, 6H), 1.71 (s, 3H, -CH_3), 1.68 (s, 3H, -CH_3), 2.12 (q, J = 6.9 Hz, 2H, Br_2C=CH-CH_2-), 3.80 (s, 3H, -CO_2CH_3), 3.82 (s, -$COOCH_3$), 5.24 (t, J = 4.8 Hz, 0.6H, -OCHRO-), 5.45 (t, J = 5.1 Hz, 0.4H, -OCHR-O), 6.38 (t, J = 7.3 Hz, 1H,-CH=$CHBr_2$); ^{13}C-NMR ($CDCl_3$) δ 18.3 (CH_3), 19.4, 21.3 (2°), 23.1 (2°), 27.3 (2°), 27.5, 29.5 (2°), 32.5 (2°), 32.7, 53.0 (-CO_2CH_3), 89.1 (Br_2C=CHR), 104.2 (-$OCCH_3(CO_2CH_3)$O-), 105.3 (-OCHRO-), 138.1 (-CH=CBr_2), 169.1 (-CO_2CH_3); IR (CH_2Cl_2) (ν, cm $^{-1}$): 2930 (C-H), 1754 (C=O), 1429, 1373, 1285, 1190, 1130; MS (m/z) (60 eV, rel. intensity): 230 (M^+-58, 13), 328 (10), 326 (7), 314 (10), 269 (25), 227 (1), 199 (20), 173 (30), 119 (100), 109 (20), 91 (35), 81 (50), 77 (30), 71 (30), 65 (20), 59 (50).

Methyl 7-(5-methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-2(*E*)heptenoate (1k): There are two different conditions (**A** and **B**) to prepare compound **1k** as a mixture of two diastereomers.

(A) Reaction with Ph_3P=CHCOOMe: To a solution of aldehyde-ozonide **1** (133.8 mg, 0.58 mmol) in 5 mL of CH_2Cl_2 was added Ph_3P=CHCOOMe (211.9 mg, 0.63 mmol) at room temperature and stirred at this temperature for 3 h. The reaction mixture was concentrated and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1k** (117.5 mg, 0.41 mmol, 71% yield).

(B) Reaction with $(EtO)_2POCHNaCO_2Me$: To a solution of methyl diethylphosphonoacetate ($(EtO)_2POCH_2CO_2Me$) (1 g, 4.76 mmol) in 10 mL of THF was added NaH (118.4 mg, 4.9 mmol) at 0 °C for 10 min. An aliquot of the resulted solution (0.72 mmol) was used in the following reaction. To a solution of aldehyde-ozonide **1** (150.7 mg, 0.65 mmol) in 5 mL of CH_2Cl_2 was added the THF solution of $(EtO)_2POCHNaCO_2Me$ (0.72 mmol) at 0 °C and stirred at this temperature for 1 h. The reaction mixture was quenched with aqueous NH_4Cl, extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), concentrated and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1k** (132.7 mg, 0.46 mmol; 71% yield).

Compound **1k**: TLC (EtOAc/Hexane = 1/3) R_f = 0.45; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.43-1.83 (m, 6H), 1.67 (s, 3H, -CH_3), 2.23 (dt, J = 12.5 and 5.7 Hz, 2H, -CH=CH-CH_2-), 3.74 (s, 3H, -CO_2CH_3), 3.83 (s, 3H, OCH_3), 5.23 (t, J = 4.8 Hz, 0.5H, -OCHRO-), 5.44 (t, J = 5.1 Hz, 0.5H,-OCHRO-), 5.82 (dt, J = 15.5 and 1.5 Hz, -CH=$CHCO_2CH_3$), 6.95 (dt, J = 15.7 and 6.9 Hz, 1H, -CH=$CHCO_2CH_3$); ^{13}C-NMR ($CDCl_3$) δ 18.5 (CH_3), 19.2, 23.1 (2°), 27.4 (2°), 27.6, 29.4 (2°), 31.7 (2°), 32.4 (2°), 51.2 (-CO_2CH_3), 52.7 (-OCH_3), 52.8, 104.0 (-$OCCH_3(CO_2CH_3)$O-), 105.2 (-OCHRO-), 121.1 (CH_3O_2CCH=CHR), 148.6 (CH_3O_2CCH=CHR), 166.8 (CO_2CH_3), 168.3 (CO_2CH_3), 168.9; IR (CH_2Cl_2) (ν, cm $^{-1}$): 2953 (C-H), 1753 (C=O), 1716 (C=O), 1433, 1374; MS (m/z) (60 eV, rel. intensity): 289 (M^++1, 1), 257 (1), 229 (2), 213 (1), 171 (28), 170 (31), 152 (13), 138 (70), 127 (26), 113 (28), 100 (11), 93 (33), 87 (10), 81 (29), 74 (6), 67 (18), 59 (32), 55 (23), 43 (100).

7-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-1-phenyl-1-oxo-2(*E*)-heptene (1m): There are two different conditions (**A** and **B**) to prepare compound **1m** as a mixture of two diastereomers.

(A) Reaction with Ph_3P=CHCOPh: To a solution of aldehyde-ozonide **1** (160.4 mg, 0.69 mmol) in 6 mL of CH_2Cl_2 was added Ph_3P=CHCOPh (289.3 mg, 0.76 mmol) at room temperature and stirred at this temperature for 6 h. The reaction mixture was concentrated and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1m** (138.4 mg, 0.41 mmol; 60% yield) and compounds **1n & 1o**.

(B) Reaction with Ph_3As=CHCOPh: To a solution of aldehyde-ozonide **1** (166.4 mg, 0.72 mmol) in 6 mL of CH_2Cl_2 was added Ph_3As=CHCOPh (336.1 mg, 0.79 mmol) at room temperature and stirred at this temperature for 1 h. The reaction mixture was concentrated and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1m** (148.4 mg, 0.44 mmol; 62% yield) and compounds **1n & 1o**.

Compound 1m: TLC (EtOAc/Hexane = 1/3) R_f = 0.5; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 1.26-1.90 (m, 6H), 1.72 (s, 3H, -C<u>H</u>$_3$), 2.34 (dt, *J* = 13.2 and 6.6 Hz, 2H, -CH=CH-C<u>H</u>$_2$-), 3.82 (s, 3H, -CO_2C<u>H</u>$_3$), 5.25 (t, *J* = 4.8 Hz, 0.7H, -OC<u>H</u>RO-), 5.46 (t, *J* = 5.1 Hz, 0.3H,-OC<u>H</u>RO-), 6.84-7.12 (m, 2H, -C<u>H</u>=C<u>H</u>-); ^{13}C-NMR ($CDCl_3$) δ 18.7 (<u>C</u>H_3), 19.4, 23.3 (2°), 27.8 (2°), 29.5 (2°), 32.4 (2°), 52.8 (-CO_2<u>C</u>H_3), 104.2 (-O<u>C</u>CH_3(CO_2CH_3)O-), 105.3 (-O<u>C</u>HRO-), 126.2, 132.6, 139.8, 149.0 (PhCOCH=<u>C</u>H-), 190.7 (C=O); IR (CH_2Cl_2) (ν, cm^{-1}): 2956 (C-H), 2936, 1753 (C=O), 1444, 1374, 1286, 1191.

8-Oxo-8-phenyl-oct-6(*E*)-enoic acid (1n): TLC (EtOAc/Hexane = 1/3) R_f = 0.17; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 1.55-1.77 (m, 4H), 2.32-2.42 (m, 4H, -CH=CH-C<u>H</u>$_2$-(CH_2)$_2$-C<u>H</u>$_2$$CO_2$H), 6.89 (dt, *J* = 15.4 and 6.7 Hz, 1H, PhCOCH=C<u>H</u>-), 7.00 (dt, *J* = 15.4 and 6.7 Hz, 1H, PhCOCH=C<u>H</u>R), 7.44-7.93 (m, 5H, Ph-H); ^{13}C-NMR ($CDCl_3$) δ 24.2 (2°), 27.5 (2°), 32.4 (2°), 33.7 (2°), 126.3, 128.5, 132.6, 137.9, 149.0 (PhCOCH=<u>C</u>H-), 178.8 (-CO_2H), 190.9 (C=O); IR (CH_2Cl_2) (ν, cm^{-1}): 2500-3500 (-OH), 2937 (C-H), 1707 (C=O), 1551, 1406, 1284, 1216, 1096; MS (m/z) (60 eV, rel. intensity): 232 (M^+, 23), 214 (4), 159 (35), 145 (11), 131 (10), 120 (10), 105 (100), 97 (11), 77 (50), 69 (15); HRMS calcd for $C_{14}H_{16}O_3$ (M^+), 232.1099, found 232.1106.

2-Methyl-4-oxo-4-phenyl-but-2(*E*)-enoic acid methyl ester (1o-*E*): TLC (EtOAc/Hexane = 1/3) R_f = 0.66; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 2.20 (d, *J* = 1.2 Hz, 3H, -CH_3), 3.85 (s, 3H, -CO_2C<u>H</u>$_3$), 7.44-7.59 (m, 3H, Ph-H), 7.72-7.95 (m, 1H, HC=C<u>H</u>COPh), 7.95-7.98 (m, 2H, PhH); ^{13}C-NMR ($CDCl_3$) δ 14.6 (-<u>C</u>H_3), 52.4 (-CO_2<u>C</u>H_3), 128.4, 128.6 (-C=<u>C</u>HCOPh), 131.8, 133.4, 137.3, 140.3 (-<u>C</u>=CHCOPh), 167.7 (-<u>C</u>O_2CH_3), 192.2 (C=O); IR (CH_2Cl_2) (ν, cm^{-1}): 2954 (C-H), 1715 (C=O), 1661, 1433, 1354, 1304, 1229, 1177, 1118. These data are in agreement with that reported in the literature.[18]

2-Methyl-4-oxo-4-phenyl-but-2(*Z*)-enoic acid methyl ester (1o-*Z*): TLC (EtOAc/Hexane = 1/3) R_f = 0.66; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 2.15 (d, *J* = 1.6 Hz, 3H, -CH_3), 3.64 (s, 3H, -CO_2C<u>H</u>$_3$), 6.76 (d, *J* = 1.6 Hz, 1H, =C<u>H</u>COPh), 7.89-7.94 (m, 5H, PhH); ^{13}C-NMR ($CDCl_3$) δ 20.1 (-<u>C</u>H_3), 52.0 (-CO_2<u>C</u>H_3), 128.5, 128.6 (-C=<u>C</u>HCOPh), 130.4, 133.2, 136.6, 140.4 (-<u>C</u>=CHCOPh), 168.5 (-<u>C</u>O_2CH_3), 191.6 (C=O); IR (CH_2Cl_2) (ν, cm^{-1}): 2954 (C-H), 1715 (C=O), 1661, 1433, 1354, 1304, 1229, 1177, 1118; MS (m/z) (60 eV, rel. intensity): 204 (M^+, 33), 189 (8), 172 (16), 145 (23), 127 (30), 117 (11), 105 (100), 77 (50); HRMS calcd for $C_{12}H_{12}O_3$ (M^+), 204.0786, found 204.0780. These data are in agreement with that reported in the literature.[18]

3-Methyl-5-(7-oxo-oct-5-enyl)-[1,2,4]trioxolane-3-carboxylic acid methyl ester (1m'): To a solution of aldehyde-ozonide **1** (140.6 mg, 0.61 mmol) in 6 mL of CH_2Cl_2 was added 2.1 mol equiv. of Ph_3P=CHCOMe (404.7 mg, 1.2 mmol) at room temperature and stirred at this temperature for 11 h. The reaction mixture was concentrated and directly treated with CH_2N_2. The crude products were chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1m'** (36.3 mg, 0.13 mmol;

60% yield), **1n'** (25.4 mg, 0.13 mmol, 22% yield), and **1o'** (*Z*-form, 12.3 mg, 0.09 mmol; *E*-form 36.8 mg, 0.26 mmol; totally 57% yield).

Compound 1m': TLC (EtOAc/Hexane = 1/3) R_f = 0.31; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 1.48-1.85 (m, 6H), 1.68 (s, 3H, -CH_3), 2.25 (dt, *J* = 3.4 and 2.9 Hz, 2H, -CH=CH-CH_2R), 3.81 (s, 3H, -CO_2CH_3), 5.24 (t, *J* = 4.9 Hz, 1H, -OCHRO-), 6.07 (dt, *J* = 15.9 and 1.5 Hz, 1H,CH=CHCOCH_3), 6.76 (dq, *J* = 9.0 and 6.9 Hz, 1H, -CH=CHCOMe); ^{13}C-NMR ($CDCl_3$) δ 18.7 (CH_3), 23.3 (2°), 26.9 (2°), 27.8 (2°), 29.5 (2°), 32.1 (RCOCH_3), 52.8 (-CO_2CH_3), 104.2 (-OCCH_3(CO_2CH_3)O-), 105.3 (-OCHRO-), 131.5 (COCH=CHR), 147.5 (COCH=CHR), 169.9 ($COOCH_3$), 198.5 ($COCH_3$); IR (CH_2Cl_2) (ν, cm^{-1}): 2934 (C-H), 1754 (C=O), 1433, 1358, 1285, 1189. MS (m/z) (60 eV, rel. intensity): 229 (M^+-43, 1), 213 (M^+-59, 8), 207 (4), 203 (M^+-69, 1), 196 (27), 168 (62), 154 (33), 137 (30), 126 (11), 121 (18), 111 (63), 97 (39), 93 (28), 83 (13), 71 (15), 67 (20), 59 (23), 55 (23), 43 (100).

8-Oxo-non-6(*E*)-enoic acid methyl ester (1n'): TLC (EtOAc/Hexane = 1/1) R_f = 0.44; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 1.45-1.72 (m, 4H), 2.24 (s, 3H, CH_3), 2.27-2.38 (m, 4H, -CH=CH-CH_2-$(CH_2)_2$-CH_2CO_2Me), 3.68 (s, 3H, $COOCH_3$), 6.08 (dt, *J* = 15.9 and 1.5 Hz, 1H, CH=CHCOMe), 6.79 (dq, *J* = 9.1 and 6.8 Hz, 1H, CH_3COCH=CHR); ^{13}C-NMR ($CDCl_3$) δ 24.3 (2°), 26.7 (2°), 27.4 (2°), 51.4 (OCH_3), 131.4 (CH=CHCOCH_3), 147.4 (CH_3COCH=CHCOCH_3), 173.6 (-CO_2Me), 198.4 (CH_3C=O); IR (CH_2Cl_2) (ν, cm^{-1}): 2500-3500 (-OH), 2937 (C-H), 1707 (C=O), 1551, 1406, 1284, 1216, 1096; MS (m/z) (60 eV, rel. intensity): 232 (M^+, 23), 214 (4), 159 (35), 145 (11), 131 (10), 120 (10), 105 (100), 97 (11), 77 (50), 69 (15); HRMS calcd for $C_{14}H_{16}O_3$ (M^+), 232.1099, found 232.1106.

2-Methyl-4-oxo-pent-2(*E*)-enoic acid methyl ester (1o'-*E*): TLC (EtOAc/Hexane = 1/1) R_f = 0.8; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 2.21 (d, *J* = 1.5 Hz, 3H, -CH=CRCH_3), 2.32 (s, 3H, -CH_3COR), 3.81 (s, 3H, $COOCH_3$), 7.09 (q, *J* = 1.7 Hz, -CH=C(CH_3)R); ^{13}C-NMR ($CDCl_3$) δ 13.9 (C=CHCH_3), 31.6 (CH_3CO), 52.1 (-CO_2CH_3), 132.3 (COCH=C(CH_3)COOMe), 139.9 (COCH=C(CH_3)CO_2Me), 167.6 (-CO_2CH_3), 198.8 (C=O); IR (CH_2Cl_2) (ν, cm^{-1}): 2954 (C-H), 1728 (C=O), 1427, 1358, 1229, 1127. These data are in agreement with that reported in the literature.[19]

2-Methyl-4-oxo-4-pent-2(*Z*)-enoic acid methyl ester (1o'-*Z*): TLC (EtOAc/Hexane = 1/1) R_f = 0.7; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 2.03 (d, *J* = 1.6 Hz, 3H, -CH=CRCH_3), 2.24 (s, 3H, -CH_3COR), 3.81 (s, 3H, $COOCH_3$), 6.20 (q, *J* = 1.7 Hz, -CH=C(CH_3)R); ^{13}C-NMR ($CDCl_3$) δ 20.0 (C=CHCH_3), 29.9 (CH_3CO), 52.2 (-CO_2CH_3), 130.3 (COCH=C(CH_3)COOMe), 140.9 (COCH=C(CH_3)CO_2Me), 169.3 (-CO_2CH_3), 197.7 (C=O); MS (m/z) (60 eV, rel. intensity): 142 (M^+, 5), 127 (22), 110 (100), 99 (16), 82 (31), 69 (13); HRMS calcd for $C_7H_{10}O_3$ (M^+), 142.0630, found 142.0633. These data are in agreement with that reported in the literature.[19]

5-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)pentanol (2): A mixture of cyclohexene (1) (1.00 g, 12.21 mmol), methyl pyruvate (1.87 g, 18.31 mmol) in 60 mL of CH_2Cl_2 was subjected to the general ozonolytic procedure. When the solution turned blue, ozone addition was stopped. Nitrogen is passed through the solution until the blue color was discharged. Removal of solvent afforded the crude products which were redissolved in 60 mL of THF. To this THF solution was added $LiBH_4$ (201.4 mg, 9.15 mmol; 0.75 mol equiv.) at 0 °C and the solution was stirred for 1 h. The reaction mixture was quenched by saturated aqueous ammonium chloride and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **2** (1.59 g, 6.81 mmol; 56% yield) as a mixture of two diastereomers in a ratio of 70:30. TLC (EtOAc/Hexane = 1/1) R_f =

0.43; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.39-2.04 (m, 8H), 1.67 (s, 3H, -CH_3), 3.64 (t, J = 6.2 Hz, 2H, RCH_2OH), 3.81 (s, 3H, -CO_2CH_3), 5.24 (t, J = 5.0 Hz, 0.7H, -OCHRO-), 5.44 (t, J = 5.2 Hz, 0.3H, -OCHRO-); ^{13}C-NMR ($CDCl_3$) δ 18.6 (CH_3), 19.4, 23.5 (2°), 25.3 (2°), 25.5, 29.7 (2°), 32.3 (2°), 32.7 (2°), 52.8 (-CO_2CH_3), 62.5 (RCH_2OH), 104.1 (-O$C$$CH_3(CO_2CH_3)$O-), 105.4 (-O-CHR-O), 168.6 (CO_2CH_3), 169.2; IR (CH_2Cl_2) (ν, cm $^{-1}$): 3618 (-OH), 2939 (C-H), 1753 (C=O), 1438, 1374, 1285, 1193; MS (m/z) (60 eV, rel. intensity): 219 (M^+-15, 8), 174 (M^+-60, 1), 161 (31), 144 (2), 128 (4), 119 (19), 115 (11), 99 (82), 81 (50), 55 (19), 43 (100).

1-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-5-acetoxypentane (2a): A solution of hydroxy-ozonide **2** (205.1 mg, 0.88 mmol), acetic anhydride (0.11 mL, 1.14 mmol), pyridine (90.2 mg, 1.14 mmol) and *N,N*-dimethylaminopyridine (DMAP) (10.7 mg, 0.09 mmol) in 5 mL of CH_2Cl_2 was stirred at this temperature for 30 min. The reaction mixture was concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **2a** (227.8 mg, 0.83 mmol; 94% yield). TLC (EtOAc/Hexane = 1/3) R_f = 0.41; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.38-1.84 (m, 8H), 1.67 (s, 3H, -CH_3), 2.04 (s, 3H, CH_3CO_2R), 2.06, 3.81 (s, 3H, -CO_2CH_3), 3.82, 4.05 (t, J = 6.5 Hz, 2H, RCH_2OCOCH_3), 5.24 (t, J = 4.9 Hz, 0.9H, -OCHRO-), 5.44 (t, J = 5.2 Hz, 0.1H, -OCHRO-); ^{13}C-NMR ($CDCl_3$) δ 18.4 (CH_3), 19.2, 20.6 (2°), 23.1 (2°), 25.5 (2°), 28.1 (2°), 29.4 (2°), 32.4 (2°), 52.5 (-CO_2CH_3), 63.9 ($CH_3CO_2CH_2$-), 103.9 (-O$C$$CH_3(CO_2CH_3)$O-), 105.1 (-O-CHR-O), 168.6 (CO_2CH_3), 170.7 (CH_3CO_2R); IR (CH_2Cl_2) (ν, cm $^{-1}$): 2956 (C-H), 1729 (C=O), 1435, 1365, 1282, 1235, 1192; MS (m/z) (60 eV, rel. intensity): 301 (M^++1, 2), 253 (1), 233 (M^+-43, 2), 217 (1), 206 (25), 201 (48), 191 (11), 174 (19), 159 (15), 119 (22), 115 (28), 99 (20), 81 (28), 43 (100).

1-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-5-*tert*-butyltrimethylsiloxylpentane (2b): A solution of hydroxy-ozonide **2** (213.5 mg, 0.92 mmol), *tert*-butyldimethylsilyl chloride (151.8 mg, 1.01 mmol) and imidazole (68.8 mg, 1.01 mmol) in 5 mL of CH_2Cl_2 was stirred at room temperature for 6 h. The reaction mixture was concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **2b** (197.8 mg, 0.59 mmol; 64% yield). TLC (EtOAc/Hexane = 1/3) R_f = 0.78; Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 0.04 (s, 6H, *t*-BuSi(CH_3)$_2$O-), 0.89 (s, 9H, $(CH_3)_3CSi(CH_3)_2$O-), 1.33-1.80 (m, 8H), 1.67 (s, 3H, -CH_3), 3.60 (t, J = 6.1 Hz, 2H, -OCH_2R), 3.81 (s, 3H, -CO_2CH_3), 5.24 (t, J = 4.7 Hz, 0.7H, -OCHRO-), 5.43 (t, J = 5.2 Hz, 0.3H, -OCHRO-); ^{13}C-NMR ($CDCl_3$) δ -5.5 (-Si(CH_3)$_2$-), 18.2 (CH_3), 18.6, 19.4, 23.3 (2°), 23.5, 25.4 (2°), 25.5, 25.8, 29.7 (2°), 32.3 (2°), 32.7, 52.6 (-CO_2CH_3), 62.7 (-SiOCH_2R), 104.0 (-O$C$$CH_3(CO_2CH_3)$O-), 105.4 (-O-CHR-O), 169.0 (CO_2CH_3); IR (CH_2Cl_2) (ν, cm $^{-1}$): 2956 (C-H), 1753 (C=O), 1434, 1374, 1255, 1190, 834; MS (m/z) (60 eV, rel. intensity): 289 (M^+-59, 30), 273 (50), 231 (67), 215 (8), 173 (100), 131 (70), 117 (23), 99 (24), 81 (32), 75 (71), 43 (42).

1-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)-5-(tetrahydropyran-2-yloxy)pentane (2c): A solution of hydroxy-ozonide **2** (205.1 mg, 0.88 mmol), 3,4-dihydro 2-*H*-pyran (83.1 mg, 0.99 mmol), PPTS (22.6 mg, 0.09 mmol) in 5 mL of CH_2Cl_2 was stirred at room temperature for 6 h. The reaction mixture was concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **2c** (276.6 mg, 0.87 mmol; 96% yield). TLC (EtOAc/Hexane = 1/3) R_f = 0.52; Pale yellow oil; ^{1}H-NMR ($CDCl_3$) δ 1.44-1.82 (m, 12H), 1.67 (s, 3H, -CH_3), 3.33-3.55 (m, 2H), 3.67-3.90 (m, 2H), 3.80

(s, 3H, -CO_2CH_3), 4.57 (t, J = 3.3 Hz, 0.6H, -OCHRO-), 4.82 (t, J = 5.3 Hz, 0.4H, -OCHRO-), 5.24 (t, J = 5.2 Hz, 0.6H, -OCHRO-), 5.44 (t, J = 5.3 Hz, 0.4H, -OCHRO-); ^{13}C-NMR ($CDCl_3$) δ 18.9 (CH_3), 20.0, 23.9 (2°), 25.7 (2°), 26.3 (2°), 29.7 (2°), 30.0 (2°), 31.0 (2°), 53.0 (-CO_2CH_3), 62.5 (-OCH_2R), 67.5 (-OCH_2R), 99.1 (-$OCH(CH_2R)O$-), 104.4 (-$OCCH_3(CO_2CH_3)O$-), 105.8 (-O-CHR-O), 169.4 (CO_2CH_3); IR (CH_2Cl_2) (ν, cm $^{-1}$): 2951 (C-H), 1754 (C=O), 1433, 1371, 1350, 1318, 1280; MS (m/z) (60 eV, rel. intensity): 318 (M^+, 2), 317 (8), 243 (4), 212 (6), 199 (70), 183 (35), 175 (70), 159 (68), 143 (6), 119 (9), 101 (56), 99 (74), 85 (100).

5-(5-Methyl-5-methoxycarbonyl-[1,2,4]trioxolan-3-yl)pentanal (1): To a solution of hydroxy-ozonide **2** (210.5 mg, 0.90 mmol) in 5 mL of CH_2Cl_2 was added pyridinium dichromate (PDC) (372.4 mg, 0.99 mmol) at 0 °C and stirred at this temperature for 5 h. Dilution of the reaction mixtures with 10 mL of ether, removal of the easily filterable precipitate, and concentration gave the crude product. The crude product was chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1** (85.9 mg, 0.37 mmol; 41%). Its spectral data is identical to the one described above.

6-Hydroxy-non-8-enal (1p): To the 8 mL of CH_2Cl_2 solution of ozonide **1b** (447.0 mg, 1.63 mmol) was added triphenylphosphine (470.29 mg, 1.79 mmol) at room temperature and stirred at this temperature for 4 h. The reaction mixture was concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give compound **1p** (203.7 mg, 1.30 mmol; 80% yield). Colorless oil; ^{1}H-NMR ($CDCl_3$) δ 1.25-1.70 (m, 6H), 1.75-1.85 (br, 1H, -OH), 2.08-2.37 (m, 2H), 2.46 (td, J = 7.0 and 1.7 Hz, 2H, -CH_2CHO), 3.61-3.68 (m, 1H, HOCHRR'), 5.01-5.19 (m, 2H, =CH_2), 5.72-5.93 (m, RCH=CH_2), 9.77 (t, J = 1.7 Hz, 1H, -CHO); ^{13}C-NMR ($CDCl_3$) δ 21.95 (2°), 25.17 (2°), 36.35 (2°), 41.94 (2°), 43.76 (2°), 70.26 (HOCHRR'), 118.13 (olefinic), 134.63 (olefinic), 202.59 (C=O); IR (CH_2Cl_2) (ν, cm $^{-1}$): 3250-3650 (br, OH), 1720 (C=O), 1637, 1386, 1248, 1096, 994, 918, 861; MS (m/z) (16 eV, rel. intensity): 157 ($M+1^+$, 3), 156 (M^+, 2), 115 (M^+-C_3H_5, 10), 97 (50), 86 (63), 84 (100), 79 (38), 69 (30); HRMS calcd for $C_9H_{16}O_2$ (M^+), 156.1151, found 156.1153. Anal. Calcd for $C_9H_{16}O_2$: C, 69.19; H, 10.32. Found: C, 69.23, H, 10.61.

Methyl 6-hydroxy-non-8-enoate (1q): To the 8 mL of CH_2Cl_2 solution of ozonide **1b** (438.1 mg, 1.60 mmol) was added triethylamine (175.0 mg, 1.73 mmol) at room temperature. The reaction mixture was quenched by 1N hydrogen chloride at 0 °C after 1 h and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated. The crude product was dissolved in CH_2Cl_2 and treated with CH_2N_2 in ether solution to give the corresponding methyl ester. The reaction mixture was concentrated and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1q** (228.7 mg, 1.33 mmol; 83% yield). Colorless oil; ^{1}H-NMR ($CDCl_3$) δ ^{1}H-NMR ($CDCl_3$) δ 1.39-1.68 (m, 6H), 2.14-2.36 (m, 4H), 3.60-3.65 (m, 1H, HOCHRR'), 3.66 (s, 3H, OMe), 5.06-5.17 (m, 2H, =CH_2), 5.73-5.94 (m, RCH=CH_2); ^{13}C-NMR ($CDCl_3$) δ 24.68, 24.99, 33.79, 36.13, 41.79, 51.26 (OCH_3), 70.22 (HOCHRR'), 117.58, 134.72, 174.00 (C=O); IR (CH_2Cl_2) (ν, cm $^{-1}$): 3250-3650 (br, OH), 1729 (C=O), 1640, 1433, 1198, 1172, 1095, 997, 909, 856; MS (m/z) (32 eV, rel. intensity): 186 (M^+, 2), 185 ($M-1^+$, 4), 145 (M^+-C_3H_5, 20), 113 (100), 95 (16), 85 (22), 67 (54); HRMS calcd for $C_{10}H_{18}O_3$ (M^+), 186.1256, found 186.1259. Anal. Calcd for $C_{10}H_{18}O_3$: C, 64.49; H, 9.74. Found: C, 64.73, H, 9.94.

4,14-Dihydroxy-8-formyl-1,8(*E*),15-heptadecatriene (1r): To 7 mL of THF solution of ozonide **1b** (438.1 mg, 1.60 mmol) was added 1N aqueous sodium hydroxide (5.8 mL, 5.8 mmol) at room temperature. The reaction mixture was quenched by 1N hydrogen chloride at 0 °C afer 16 h and extracted with CH_2Cl_2. The organic layer was dried (Na_2SO_4), filtered, concentrated, and chromatographed on a silica gel column by elution with EtOAc/hexane to give the desired product **1r** (216.7 mg, 0.73 mmol; 92% yield). Colorless oil; ^{1}H-NMR ($CDCl_3$) δ ^{1}H-NMR ($CDCl_3$) δ 1.33-1.62 (m, 10H), 1.70-2.00 (br, 2H, -OH), 2.16-2.40 (m, 8H), 3.62-3.68 (m, 2H, HOC<u>H</u>RR'), 5.07-5.19 (m, 4H, =C<u>H</u>$_2$), 5.72-5.89 (m, RC<u>H</u>=CH$_2$), 6.47 (t, *J* = 7.4 Hz, 1H, RC<u>H</u>=CR'CHO), 9.36 (s, 1H, -C<u>H</u>O); ^{13}C-NMR ($CDCl_3$) δ 23.77, 24.80, 25.47, 28.63, 28.89, 36.45, 42.03, 70.39 (HO<u>C</u>HRR'), 118.06, 118.23, 134.66, 134.76, 143.59, 155.28, 195.27 (C=O); IR (CH_2Cl_2) (ν, cm^{-1}): 3250-3650 (br, OH), 1680 (C=O), 1640, 1605, 1250, 1102; MS (m/z) (32 eV, rel. intensity): 186 (M^+, 2), 185 ($M-1^+$, 4), 145 ($M^+-C_3H_5$, 20), 113 (100), 95 (16), 85 (22), 67 (54); HRMS calcd for $C_{18}H_{30}O_3$ (M^+), 186.1256, found 186.1259. Anal. Calcd for $C_{18}H_{30}O_3$: C, 73.93; H, 9.65. Found: C, 74.06, H, 9.71.

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