Preparation of Dimethyl 7-Oxobicyclo[2.2.1]heptane-*exo*-2,*exo*-3-dicarboxylate. An Easy Route to Functionalized Norbornane Derivatives and Cage Compounds

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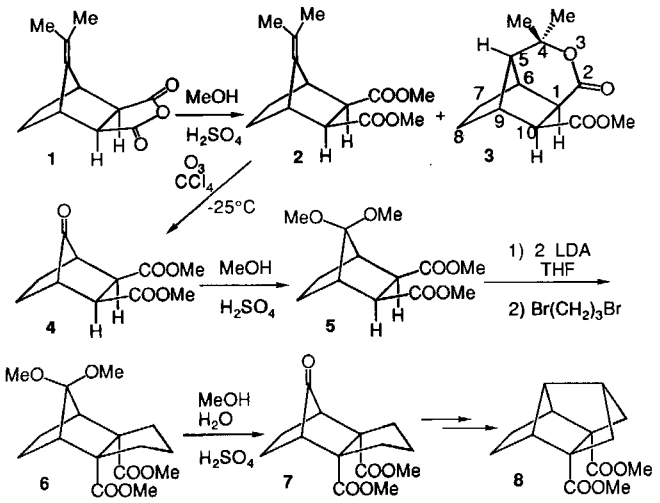
A four-step preparation of dimethyl 7-oxobicyclo[2.2.1]-heptane-*exo*-2,*exo*-3-dicarboxylate (**4**) in satisfactory yield from the readily available 6,6-dimethylfulvene and maleic anhydride is described. Compound **4** represents a well-functionalized intermediate for the synthesis of norbornane derivatives which is used for an improved synthesis of the tricyclic diester **7**, precursor of the cage compound **8**. An alternative approach to diester **7** from dimethyl 7-isopropylidenebicyclo[2.2.1]heptane-*exo*-2,*exo*-3-dicarboxylate (**2**) is also discussed.

Some time ago, we have published[1] a synthesis of dimethyl tetracyclo[5.2.1.$0^{2,6}$.$0^{3,8}$]decane-7,8-dicarboxylate (**8**), a compound of interest in connection with the synthesis of polyquinanes. This compound is easily prepared by intramolecular carbene insertion reaction of the oxo diester **7**. The synthesis of **7** may be carried out by two different routes. However, **8** is not available in gram quantities as both routes suffer from serious drawbacks. In one case, a poorly stereoselective Diels-Alder reaction of the expensive 1-cyclopentene-1,2-dicarboxylic anhydride[2] with 6,6-dimethylfulvene is the key step. In the other route, the difficultly accessible and unstable 5,5-diethoxycyclopentadiene[3] is produced as an intermediate.

In this paper we describe a highly improved synthesis of oxo diester 7 from **1** (Scheme 1), readily accessible by hydrogenation of the Diels-Alder *exo* adduct of 6,6-dimethylfulvene with maleic anhydride[4]. The key intermediate in this synthesis is dimethyl 7-oxobicyclo[2.2.1]heptane-*exo*-2,*exo*-3-dicarboxylate (**4**), a well-functionalized compound of great interest for the synthesis of a variety of norbornane derivatives with potential pharmacological activity.

Scheme 1

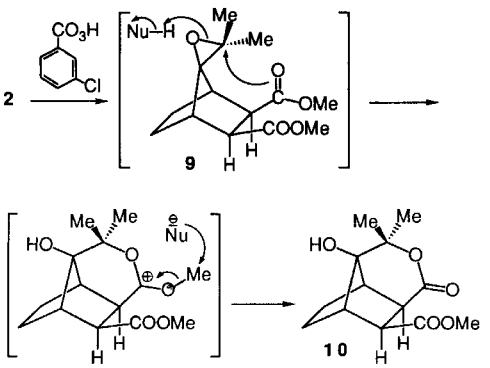


Compound **1** is transformed into the corresponding dimethyl ester **2**[4] by reaction with anhydrous methanol and concentrated sulfuric acid at room temperature for 18 h (70% yield). A minor component of this reaction, isolated from the mother liquors of crystallization, has been unambiguously characterized as methyl (1*RS*,5*RS*,6*SR*,9*RS*,10*SR*)-4,4-dimethyl-2-oxo-3-oxatricyclo[4.4.0.$0^{5,9}$]decane-10-carboxylate (**3**).

Ozonization of **2** is carried out by bubbling a stream of ozone-containing oxygen (approx. 3% ozone) through a CCl_4 solution of **2** at −25°C until the solution becomes blue-violet. The reaction mixture is then hydrogenated at atmospheric pressure by using 10% Pd on charcoal as catalyst until no more hydrogen is absorbed. Crystallization of the crude product from 2-propanol gives dimethyl 7-oxobicyclo[2.2.1]heptane-*exo*-2,*exo*-3-dicarboxylate (**4**) in 68% yield. Two byproducts are formed in low yields in this reaction (less than 5% as determined by GLC). One of them is isolated from the mother liquors of **4** by column chromatography, crystallized from toluene, and characterized as methyl (1*RS*,5*SR*,6*RS*,9*SR*,10*SR*)-5-hydroxy-4,4-dimethyl-2-oxo-3-oxatricyclo[4.4.0.$0^{5,9}$]decane-10-carboxylate[5] (**10**) (Scheme 2). The other one is identified as the lactone **3**. The proportion of compound **10** formed in this reaction seems to increase with rising polarity of the solvent and temperature of the reaction mixture. However, in each case oxo diester **4** is the major reaction product.

The formation of **10** in the ozonization of **2** may be explained by initial epoxidation of the C=C bond to epoxide **9**, followed by intramolecular nucleophilic opening (Scheme 2). To support this hypothesis, compound **2** is epoxidized with *m*-chloroperbenzoic acid in CH_2Cl_2 to a mixture of two

Scheme 2

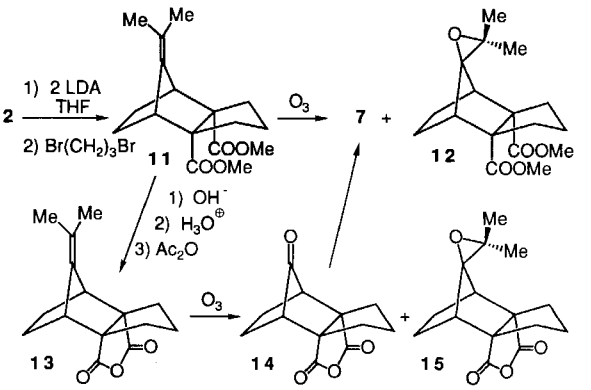


products. The less polar product (GLC) is transformed on standing into the other one which has been shown to be **10**. Attempts to isolate or record NMR spectra of this unstable compound have failed. Its probable structure **9** is shown in Scheme 2, corresponding to the epoxidation of **2** from the less hindered C=C bond face. In fact, we have previously observed an epoxidation proceeding with the same stereoselectivity during the ozonization of a related compound[6]. In certain cases we have detected in crude mixtures from the ozonization of diester **2** the presence of an elusive compound whose retention time (GLC) is the same as that of the unstable product formed by epoxidation of **2**. It is worth mentioning that compound **10** is the only product obtained in the ozonization of disodium 7-isopropylidenebicyclo-[2.2.1]heptane-*exo*-2,*exo*-3-dicarboxylate, followed by esterification of the corresponding monocarboxylic acid with an ethereal solution of diazomethane[5].

The transformation of oxo diester **4** into the tricyclic compound **7** has easily been carried out according to our prior experience[1]. The reaction of compound **4** with anhydrous methanol and concentrated H_2SO_4 gives dimethyl (1*R*,2*R*,3*S*,4*S*)-7,7-dimethoxybicyclo[2.2.1]heptane-*exo*-2,*exo*-3-dicarboxylate (**5**) in 97% yield. Treatment of diester **5** with 2 equivalents of LDA in anhydrous THF solution followed by alkylation with 1,3-dibromopropane affords, after column chromatography, dimethyl (1*R*,2*S*,6*R*,7*S*)-10,10-dimethoxytricyclo[5.2.1.$0^{2,6}$]decane-2,6-dicarboxylate (**6**) in 56% yield. The stereochemistry of this compound has clearly been established by acid hydrolysis (92% yield) to the known[6] tricyclic oxo diester **7**.

We have also studied another approach to **7** starting from **2** (Scheme 3). The reaction of **2** with 2 equivalents of LDA in anhydrous THF solution followed by treatment with 1,3-dibromopropane furnishes, after column chromatography, the known[6] tricyclic diester **11** in 54% yield. However, its ozonization (CH_2Cl_2, −78 °C) affords a 1:5 mixture (GLC) of oxo diester **7** and epoxy diester **12**. Similar results are obtained in CCl_4 at −30 °C and in cyclohexane at −78 °C [ratios (GLC): **7**:**12** = 1:8 and 1:16, respectively]. This result is in striking contrast to the ozonization[6] of the corresponding anhydride **13**, [ratio (GLC) of the products obtained: **15**:**14** = 2:1]. An attempt to transform diester **11** into the oxo diester **7** by oxygen electron-transfer oxidation using tris(2,4-dibromophenyl)ammoniumyl hexachloroantimonate as catalyst[7] has failed, the starting compound remaining unchanged.

Scheme 3



To avoid this drawback, we have transformed diester **11** into the anhydride **13** by standard procedures and have studied the ozonization of **13** under different conditions. The results obtained are collected in Table 1. As can be seen, ketone **14** or epoxide **15** is the major reaction product, depending on the reaction conditions. As in the ozonization of diester **2**, the formation of the epoxy derivative seems to increase with increasing polarity of the solvent and temperature of the reaction mixture. The ozonization of **13** in CCl_4 solution at −25 °C represents an improvement of the described reaction[6] affording oxo anhydride **14**.

Table 1. GLC analysis of the products obtained by ozonization of anhydride **13** under different conditions

Solvent	T [°C]	**14**:**15**
CCl_4	−25	4 :1
CCl_4	0	2.7:1.0
CCl_4/CH_2Cl_2 (9:1)	−30	3 :1
CH_2Cl_2	−78	2 :1
CH_2Cl_2	0	1.0:1.3
EtOAc	0	1 :1
MeOH	0	1.0:1.7

Since oxo anhydride **14** has previously been transformed[6] into oxo diester **7**, the sequence **2** → **11** → **13** → **14** → **7** constitutes an alternative route to **7** which is shorter and furnishes a higher overall yield than those previously described[1,6]. However, the preparation of **7** illustrated in Scheme 1 is preferred because of its greater experimental simplicity, absence of redundant transformations, and higher yields.

In summary, we have developed an easy access to oxo diester **4**, a well-functionalized norbornane derivative, whose application for the synthesis of complex polycyclic compounds such as **7**, from which **8** derives, has been described in this paper. The utility of **4** for the synthesis of compounds with potential pharmacological activity is under study.

We thank Dr. *C. Celma* and Dr. *M. Feliz* from the University of Barcelona, for recording the mass and NMR spectra, respectively.

Experimental

IR: Perkin-Elmer 1430 spectrometer. – 200-MHz ^{1}H NMR and 50.3-MHz ^{13}C NMR: Varian XL 200 or Gemini 200 spectrometers, internal TMS. – GLC: Perkin-Elmer model F-11. – GLC/MS: Hewlett-Packard model 5988A spectrometer, connected to a Hewlett-Packard model 5890 chromatograph, column 12 m × 0.2 mm, cross-linked methylsilicone. – Column chromatography: Merck 60 (0.063–0.200 mm) silica gel. – Melting points, corrected: Büchi (open capillary tubes). – Ozonizations: Ozonair model L60. – Microanalyses: Mycroanalysis Service of the Centro de Investigación y Desarrollo, C.S.I.C., Barcelona, Spain.

Dimethyl 7-Isopropylidenebicyclo[2.2.1]heptane-exo-2,exo-3-dicarboxylate (**2**) *and Methyl (1RS,5RS,6SR,9RS,10SR)-4,4-Dimethyl-2-oxo-3-oxatricyclo[4.4.0.0^{5,9}]decane-10-carboxylate* (**3**): To a solution of concd. H_2SO_4 (12 ml, 0.21 mol) and anhydrous methanol (228 ml) anhydride **1** (9.3 g, 45 mmol) was added and the mixture stirred at room temp. for 18 h. The cold solution (ice bath) was added with stirring to K_2CO_3 (32 g, 0.23 mol) and filtered. The precipitate was washed with CH_2Cl_2 (50 ml), and the combined organic filtrates and washings were concentrated at reduced pressure. The residue was dissolved in CH_2Cl_2 (150 ml), dried (Na_2SO_4), and concentrated in vacuo to give 10.8 g of a solid mixture of diester **2** and lactone **3** (93:7 by GLC). Crystallization from 2-propanol gave 7.9 g (70%) of **2**, m.p. 99–101°C [ref.[4] 103–105°C (ethyl acetate)]. From the mother liquors, lactone **3**, m.p. 126–127°C (toluene), was isolated.

3: IR (CCl_4): $\tilde{\nu}$ = 1745 cm^{-1} (s). – ^{1}H NMR ($CDCl_3$): δ = 1.32–1.54 [m, s (1.40), s (1.45), 7-H_{endo}, 8-H_{endo}, $C(CH_3)_2$], 1.58–1.78 (m, 8-H_{exo}), 1.80–1.94 (m, 7-H_{exo} 5-H), 2.57 (d, J = 8.0 Hz, 10-H), 2.63 (m, 6-H), 2.95 (m, dt, J = 8.0 Hz, J' = 1.3 Hz, 9-H, 1-H), 3.67 (s, CO_2CH_3). – ^{13}C NMR ($CDCl_3$): δ = 25.0 (C-7), 26.1 (*endo*-CH_3), 30.9 (*exo*-CH_3), 31.7 (C-8), 38.6 (C-9), 39.7 (C-6), 48.3, 48.8 (C-1, C-10), 51.9 (OCH_3), 54.1 (C-5), 82.5 (C-4), 172.0, 172.1 (CO_2CH_3, C-2). – MS (EI): *m/z* (%) = 239 (0.8), 238 (0.6), 224 (9), 223 (66), 207 (3), 194 (10), 192 (5), 191 (41), 189 (8), 164 (5), 163 (33), 162 (9), 161 (7), 153 (11), 151 (8), 138 (19), 135 (25), 134 (19), 133 (9), 125 (6), 121 (19), 120 (5), 119 (8), 114 (23), 113 (15), 107 (25), 106 (9), 105 (12), 97 (9), 95 (13), 93 (22), 92 (9), 91 (41), 87 (21), 83 (13), 82 (100), 81 (9), 80 (6), 79 (25), 78 (8), 77 (23), 74 (6), 69 (8), 68 (6), 67 (38), 66 (5), 65 (17), 59 (15), 57 (7), 55 (12), 53 (10), 43 (30), 41 (16).

$C_{13}H_{18}O_4$ (238.28) Calcd. C 65.53 H 7.61
Found C 65.50 H 7.59

Dimethyl 7-Oxobicyclo[2.2.1]heptane-exo-2,exo-3-dicarboxylate (**4**) *and Methyl (1RS,5SR,6RS,9SR,10SR)-5-Hydroxy-4,4-dimethyl-2-oxo-3-oxatricyclo[4.4.0.0^{5,9}]decane-10-carboxylate* (**10**): Through a solution of diester **2** (5.0 g, 19.8 mmol) in CCl_4 (150 ml) at –25°C (acetone/CO_2 bath) an ozone stream was bubbled until the solution became blue-violet (ozone in solution). Then, 10% Pd on charcoal (250 mg) was added and the mixture hydrogenated at atmospheric pressure until no more hydrogen absorption was observed (approx. 6 h). The mixture was filtered and the solvent evaporated at reduced pressure. A GLC analysis showed that the residue consisted of a mixture of oxo diester **4**, hydroxy lactone **10**, and lactone **3** (ratio **4**:**10**:**3** = 92:5:3). Crystallization from 2-propanol (4.5 ml) gave **4** (2.9 g, 64% yield), m.p. 70–71°C (recrystallized from 2-propanol). Concentration of the filtrates corresponding to several batches afforded a little more of **4** (68% total yield). From the mother liquors, after column chromatography (silica gel, hexane/ethyl acetate) and crystallization from toluene, a pure sample of hydroxy lactone **10** (60 mg, 1%) was obtained, m.p. 188–189°C (toluene) [ref.[5] 201°C (methanol)].

4: IR (CCl_4): $\tilde{\nu}$ = 1785 cm^{-1} (s), 1745 (s). – ^{1}H NMR ($CDCl_3$): δ = 1.65 [m, 5(6)-H_{endo}], 2.00 [m, 5(6)-H_{exo}], 2.34 (dd, J = 2.0 Hz, J' = 2.8 Hz, 1(4)-H], 3.08 [s, 2(3)-H], 3.65 (s, 2 CO_2CH_3). – ^{13}C NMR ($CDCl_3$): δ = 21.8 [C-5(6)], 40.4 [C-1(4)], 45.5 [C-2(3)], 51.8 (CO_2CH_3), 171.8 (CO_2CH_3), 210.2 (CO). – GLC/MS (CI, CH_4): *m/z* (%) = 227 (12) [M^+ + 1], 196 (14), 195 (100) [M^+ – MeO].

$C_{11}H_{14}O_5$ (226.23) Calcd. C 58.40 H 6.24
Found C 58.46 H 6.24

10: IR (KBr): $\tilde{\nu}$ = 3480 cm^{-1} (m), 1740 (s), 1700 (s). – ^{1}H NMR ($CDCl_3/CD_3OD$): δ = 1.3–1.6 [m, s (1.46), s (1.47), 7-H_{endo}, 8-H_{endo}, $C(CH_3)_2$], 2.0–2.4 [m, 7-H_{exo}, 8-H_{exo}], 2.43 (d, J = 4.8 Hz, 6-H), 2.72 (d, J = 8.5 Hz, 10-H), 2.76 (dd, J = 3.5 Hz, J' = 1.1 Hz, 9-H), 2.94 (dd, J = 8.5 Hz, J' = 8.5, J'' = 1.1 Hz, 1-H), 3.67 (s, CO_2CH_3), 4.20 (br., OH). – ^{13}C NMR ($CDCl_3/CD_3OD$): δ = 22.5 (*endo*-CH_3), 24.1 (C-7), 27.2 (*exo*-CH_3), 30.0 (C-8), 41.6 (C-9), 42.1 (C-6), 48.4, 48.5 (C-1, C-10), 51.6 (CO_2CH_3), 83.6 (C-4), 86.4 (C-5), 171.9, 172.7 (C-2, CO_2CH_3). – GLC/MS (CI, CH_4): *m/z* (%) = 256 (13), 255 (100) [M^+ + 1], 238 (10), 237 (69), 223 (30).

Epoxidation of Diester **2**: To a cold (0°C) solution of diester **2** (47 mg, 0.19 mmol) in CH_2Cl_2 (2 ml) *m*-chloroperbenzoic acid (55 mg, 0.28 mmol) was added and the mixture stirred at this temp. for 30 min. The solution was washed with aqueous Na_2CO_3, dried with Na_2SO_4, and concentrated at reduced pressure to give a mixture of **10** and a less polar product (GLC) (42 mg). After the reaction mixture had been stored for several hours, only hydroxy lactone **10** was obtained (41 mg, 84%). All attempts to isolate the less polar product (crystallization or column chromatography) were fruitless.

Dimethyl 7,7-Dimethoxybicyclo[2.2.1]heptane-exo-2,exo-3-dicarboxylate (**5**): To a solution of concd. H_2SO_4 (2.5 ml, 46 mmol) in anhydrous methanol (50 ml) ketone **4** (1.5 g, 6.63 mmol) was added and the mixture stirred at room temp. for 18 h. The cold solution (ice bath) was added with stirring to anhydrous K_2CO_3 (6.5 g, 47 mmol) and filtered. The precipitate was washed with CH_2Cl_2, and the combined filtrates and washings were evaporated at reduced pressure. The residue was disolved in CH_2Cl_2, dried (Na_2SO_4), and concentrated in vacuo to give acetal **5** (1.75 g, 97%) as an oil (pure according to GLC), b.p. 160°C (oven)/0.1 Torr. – IR (CCl_4): $\tilde{\nu}$ = 1745 cm^{-1} (s). – ^{1}H NMR ($CDCl_3$): δ = 1.27 [m, 5(6)-H_{endo}], 1.84 [m, 5(6)-H_{exo}], 2.58 [m, 1(4)-H], 2.82 [s, 2(3)-H], 3.26 (s, OCH_3), 3.27 (s, OCH_3), 3.68 (s, 2 CO_2CH_3). – ^{13}C NMR ($CDCl_3$): δ = 26.7 [C-5(6)], 40.9 [C-1(4)], 48.8 [C-2(3)], 50.4 (OCH_3), 51.0 (OCH_3), 51.3 (CO_2CH_3), 113.1 (C-7), 172.7 (CO_2CH_3).

$C_{13}H_{20}O_6$ (272.30) Calcd. C 57.34 H 7.38
Found C 57.36 H 7.31

Dimethyl (1RS,2SR,6RS,7SR)-10,10-Dimethoxytricyclo[5.2.1.0^{2,6}]decane-2,6-dicarboxylate (**6**): Lithium diisopropylamide was prepared by treating a solution of anhydrous diisopropylamine (6.13 ml, 43.4 mmol) in anhydrous THF (20 ml) with a 1.6 N solution of butyllithium in hexane (26 ml, 41.6 mmol) at –78°C (acetone/CO_2 bath) under argon. The solution was allowed to warm to 0°C (ice/water bath) and then cooled to –78°C. A solution of acetal **5** (5.1 g, 18.8 mmol) in anhydrous THF (20 ml) was added dropwise with magnetic stirring keeping the reaction mixture at this temp. for 4 h after completion of the addition. Then, 1,3-dibromopropane (1.92 ml, 18.8 mmol) was added at once, the mixture allowed to warm to 0°C, and kept at this temp. for 48 h. The mixture was acidified with 6 N HCl, the organic solvents were evaporated at reduced pressure, and the residue was extracted with $CHCl_3$ (3 × 50 ml). The combined organic extracts were washed with water, dried with Na_2SO_4, and concentrated in vacuo. The crude product was chromatographed on silica gel with hexane/ethyl acetate to afford the solid diester **6** (3.38 g, 56% yield), m.p. 80–81°C (methanol). – IR (CCl_4): $\tilde{\nu}$ = 1720 cm^{-1} (s). – ^{1}H NMR ($CDCl_3$): δ = 1.5–2.4 (m,

12 ring protons), 3.21 (s, OCH_3), 3.23 (s, OCH_3), 3.62 (s, 2 CO_2CH_3). – ^{13}C NMR ($CDCl_3$): δ = 22.1 [C-8(9)], 25.6 (C-4), 37.8 [C-3(5)], 45.9 [C-1(7)], 49.3 (OCH_3), 50.3 (OCH_3), 51.1 (CO_2CH_3), 63.6 [C-2(6)], 113.4 (C-10), 175.8 (CO_2CH_3).

$C_{16}H_{24}O_6$ (312.36) Calcd. C 61.52 H 7.74
Found C 61.55 H 7.70

Dimethyl (1RS,2SR,6RS,7SR)-10-Oxotricyclo[5.2.1.0^{2,6}]decane-2,6-dicarboxylate (**7**): To a solution of concd. H_2SO_4 (3.7 ml), water (30 ml), and methanol (50 ml) acetal **6** (3.54 g, 13.3 mmol) was added and the mixture stirred for ca. 12 h at room temp. The mixture was made alkaline with aqueous 1 M Na_2CO_3, the organic solvent evaporated at reduced pressure, and the residue extracted with $CHCl_3$ (3 × 30 ml). The combined organic extracts were washed with water, dried with Na_2SO_4, and concentrated in vacuo to give diester **7** (2.77 g, 92% yield), identical with an authentic sample[6].

Dimethyl (1RS,2RS,6SR,7SR)-10-Isopropylidenetricyclo[5.2.1.0^{2,6}]-decane-2,6-dicarboxylate (**11**): Lithium diisopropylamide was prepared by treating a solution of freshly distilled anhydrous diisopropylamine (4.8 ml, 35.2 mmol) in anhydrous THF (20 ml) with a 1.6 N solution of butyllithium in hexane (21 ml, 33.6 mmol) at −78 °C (acetone/CO_2 bath) under argon. The solution was allowed to warm to 0 °C (ice/water bath) and then cooled to −78 °C. A solution of diester **2** (4.1 g, 16 mmol) in anhydrous THF (27 ml) was added dropwise with stirring keeping the reaction mixture at this temp. for 1 h after completion of the addition. Then, 1,3-dibromopropane (3.2 g, 16 mmol) was added at once, the mixture allowed to warm to 0 °C, and kept at this temp. for 2 h. The mixture was acidified with 6 N HCl and extracted with diethyl ether (3 × 30 ml). The combined organic extracts were washed with water, dried with Na_2SO_4, and concentrated in vacuo. The crude product was chromatographed on silica gel with hexane/ethyl acetate to give 4.0 g of a viscous oil that crystallized from methanol to yield diester **11** (2.56 g, 54%), m.p. 39–40 °C [ref.[6] 50–51 °C (methanol)].

Ozonization of Diester **11**. – *Dimethyl (1'RS,2'SR,6'RS,7'SR, 10's-meso)-3,3-Dimethylspiro[oxirane-2,10'-tricyclo[5.2.1.0^{2,6}]decane]-2',6'-dicarboxylate* (**12**) *and Oxo Diester* **7**: Through a solution of diester **11** (30 mg, 0.10 mmol) in CH_2Cl_2 (20 ml) at −78 °C (acetone/CO_2 bath) an ozone stream was bubbled until the solution became blue-violet (ozone in solution). PtO_2 dioxide (0.3 mg) was added and the mixture hydrogenated at atmospheric pressure for 12 h. The catalyst was filtered off; a GLC analysis revealed that the filtrate contained oxo diester **7** and epoxy diester **12** (ratio **7**:**12** = 1:5). Similar results were obtained in cyclohexane at −78 °C (ratio **7**:**12** = 1:16) and CCl_4 at −30 °C (ratio **7**:**12** = 1:8). Physical and spectroscopic data of epoxy diester **12** 〈isolated by crystallization (633 mg, 60%) after reaction of a mixture of **7** + **12** (ratio 1:8) [from **11** (1000 mg, 3.4 mmol)] with *p*-toluenesulfonylhydrazine[1] (186 mg, 1.0 mmol)〉: m.p. 112–113 °C (2-propanol/water). – IR (KBr): $\tilde{\nu}$ = 1725 cm^{-1} (s). – ^1H NMR ($CDCl_3$): δ = 1.42 [s, $(CH_3)_2C$], 1.5–2.0, 2.3–2.45 (complex absorption, 12 ring protons), 3.66 (s, 2 CH_3O). – ^{13}C NMR ($CDCl_3$), δ = 22.8 [C-8'(9')], 23.2 [$(CH_3)_2C$], 25.3 (C-4'), 38.4 [C-3'(5')], 46.5 [C-1'(7')], 51.6 (2 CO_2-CH_3), 62.0 [C-2'(6')], 64.8 [C-3], 80.9 (C-10'), 174.7 (2 CO_2CH_3).

$C_{17}H_{24}O_5$ (308.38) Calcd. C 66.21 H 7.84
Found C 66.34 H 7.97

(1RS,2RS,6SR,7SR)-10-Isopropylidenetricyclo[5.2.1.0^{2,6}]decane-2,6-dicarboxylic Anhydride[6] (**13**): Diester **11** (840 mg, 2.9 mmol) was added to a solution of NaOH (468 mg, 11.7 mmol) in methanol (10 ml) and water (7 ml), and the mixture was heated under reflux for 18 h. The organic solvent was evaporated at reduced pressure and the residue acidified with 6 N HCl and extracted with diethyl ether (3 × 30 ml). The combined organic extracts were dried with Na_2SO_4, and the solvent was removed in vacuo. The residue was treated with acetic anhydride (15 ml) under reflux for 1 h. The volatile compounds were evaporated at reduced pressure, and the residue was sublimed to give anhydride **13** (640 mg, 90%).

Ozonization of Anhydride **13**[6]. – *Epoxy Anhydride* **14** *and Oxo Anhydride* **15**: Ozonization was carried out as described for diester **11**. The reaction conditions and ratios of products are listed in Table 1. In all cases, the reaction was stopped after consumption of all of the starting compound, **14** and **15** being the only reaction products detected by GLC.

CAS Registry Numbers

(*meso*)-**1**: 51606-73-6 / (*meso*)-**2**: 72407-16-0 / (±)-**3**: 126664-45-7 / (*meso*)-**4**: 126664-46-8 / (*meso*)-**5**: 126664-47-9 / (*meso*)-**6**: 126664-48-0 / (*meso*)-**7**: 93248-43-2 / (±)-**10**: 126664-49-1 / (*meso*)-**11**: 95924-58-6 / (*meso*)-**12**: 126664-50-4 / (*meso*)-**13**: 95924-56-4 / (*meso*)-**14**: 95924-61-1 / (*meso*)-**15**: 95924-62-2

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