A Facile and General Entry to Optically Active Pheromones and Aromas With γ-Alkyl-γ-lactone Structures. A Study of Some Lactone Derivatives of Pentoses [1]

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A new and easy general methodology has been developed to prepare γ-alkyl-α,β-butenolides or γ-alkylbutyrolactones in four and five steps, respectively, from D-ribonolactone as a common chiral starting material. Some of these products have pheromonal activity in insects and are also used as fruit fragrances. A study on several derivatives of D-ribonolactone and 2-deoxy-D-ribonolactone has been carried out in order to explore alternative routes for these syntheses.

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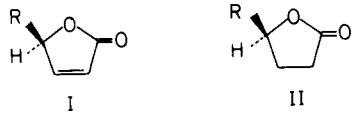
Introduction.

α,β-Unsaturated and saturated γ-lactones, I and II, are interesting molecules subjected to several studies, since they are components of natural flavours [2], have pheromonal activity in insects and some of them are key intermediates in the synthesis of other natural products.

Generally, racemic mixtures of these lactones are used in the perfume and food industries (*e.g.* racemic IIc is used as a coconut flavouring [3]) but for the last two purposes indicated above, optically active compounds are especially important and needed. Thus, (+)-γ-caprolactone, IIb, has activity as attractant pheromone of several *Trogoderma* species of dermestid beetles [4] and it has been used by Silverstein [5] to synthesize chalcograne, the principal component of the aggregation pheromone of the beetle *Pityogenes chalcographus*. The (−)-γ-ethylbutenolide Ib is the starting material in a synthesis of (−)-4-methyl-3-heptanol, aggregation pheromone of the smaller european elm bark beetle *Scolytus multistratus* [6]. Finally (+)-γ-pelargonolactone, IIc, is a repellent for dogs and cats from a selected area or from each other [7] and attractant for rice weevil *Sitophilus zeamais* Motchulsky [8].

Scheme 1



I II

R=CH_3	Ia	IIa
C_2H_5	Ib	IIb
n-C_5H_{11}	Ic	IIc

In this paper we describe the synthesis from commercially available D-ribolactone, III, as a common chiral starting material, of the following lactones: (−)-*(R)*-5-ethyl-2(5*H*)-furanone, Ib (−)-*(R)*-5-pentyl-2(5*H*)-furanone, Ic, (+)-*(R)*-5-ethyldihydro-2(3*H*)-furanone, IIb, and (+)-*(R)*-5-pentyldihydro-2(3*H*)-furanone, IIc, chosen as representative examples of a generalized method. Recently, we have reported [9] the synthesis of the lower terms of these series, Ia and IIa, following another synthetic methodology.

Results and Discussion.

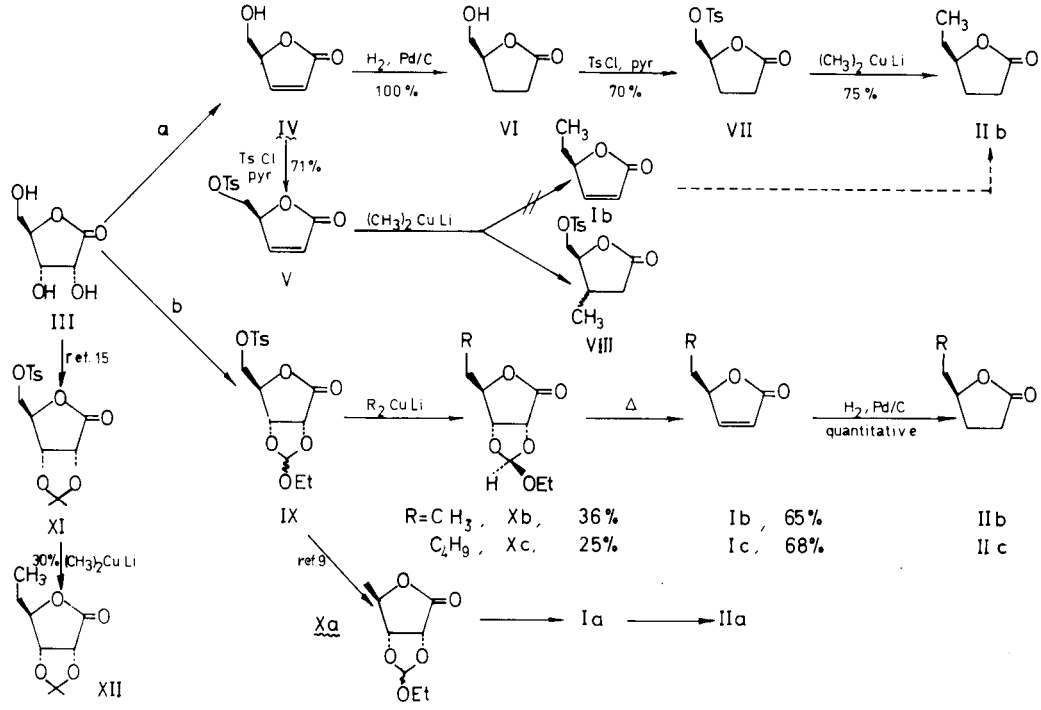
In spite of several methods described in the literature for the preparation of racemic γ-lactones of the type I and II, only two ways are reported to lead optically active saturated and α,β-unsaturated γ-alkyl-γ-lactones. These methods either start from 4-hydroxy-2-alkinoates (obtained by enantioselective reduction of the appropriate ketones) [10,11], or from L-glutamic acid as a chiral precursor [12].

The convenience to use D-ribonolactone as starting material to obtain chiral γ-lactones had already been shown by us [13,14] and is now confirmed in the preparation of the previously described (+)-γ-pelargonolactone, IIc, through the strategy depicted in Scheme 2, arrow **a**, that passes by the early formation of the α,β-double bond.

Thus, we have prepared the tosylate VII by reaction of *p*-toluenesulfonyl chloride with (+)-γ-hydroxymethyl-γ-butyrolactone, VI, resulting from quantitative catalytic hydrogenation of the butenolide IV, easily synthesized from III [14]. When tosylate VII was made to react with lithium dibutyl cuprate, as in the last step of the sequence described by Silverstein [12], IIc was obtained in 35% overall yield from III, twice as much as that already reported by this author starting from L-glutamic acid.

A modification of the strategy **a**, that would afford butenolides I as well as butanolides II by catalytic hydrogenation, passes through the tosylate V that can easily be prepared from γ-hydroxymethyl-α,β-butenolide, IV, However, the reaction of V with lithium dimethyl cuprate affords VIII as the only identified product among much polymeric material.

Scheme 2



The major reactivity of the conjugated system as a Michael acceptor and the facility of substrate V or similars to perform elimination reactions [9] seems to preclude this order of bond formation. Therefore, alkylation must be performed before formation of the C-C double bond; this strategy is depicted in Scheme 2, arrow **b**. Thus tosylate IX [14] was made to react with lithium dimethyl or dibutyl cuprates to give the orthoesters Xb or Xc in 36% and 25% yield, respectively. Subsequent pyrolysis [13,14] of Xa afforded the butenolide Ib in 65% yield, that by catalytic hydrogenation led quantitatively to the saturated lactone IIb. In the same way, IIc was prepared from Xc through the butenolide Ic, in 68% yield.

The alkylation step has low yields. Although the tosylate orthoester IX is a diastereoisomeric mixture (as shown clearly by its cmr spectrum that shows double bands for all carbon atoms), the product after reaction with alkyl cuprates was always in a single isomeric form, presumably the epimer that has the formate proton *endo*. This result led us to think that abstraction of the proton *exo* by the basic reaction medium would generate a carbanion that by further evolution into polymers would explain the lower yields of the alkylation. That the formate proton is active in the reaction medium of lithium alkyl cuprates was confirmed by treatment of the diastereoisomeric mixture of the orthoester Xa [9] with two equivalents of lithium dimethyl cuprate in the usual reaction conditions: only 30% of the starting material (although as a mixture of diastereoisomers) was recovered together with tar. This experiment does not explain however the disappearance of one of the diastereoisomers.

In order to completely verify that the proton of the orthoester function plays some role in the alkylation step, we studied the reaction of the tosylate acetonide XI [15] with lithium dimethyl cuprate, to give XII.

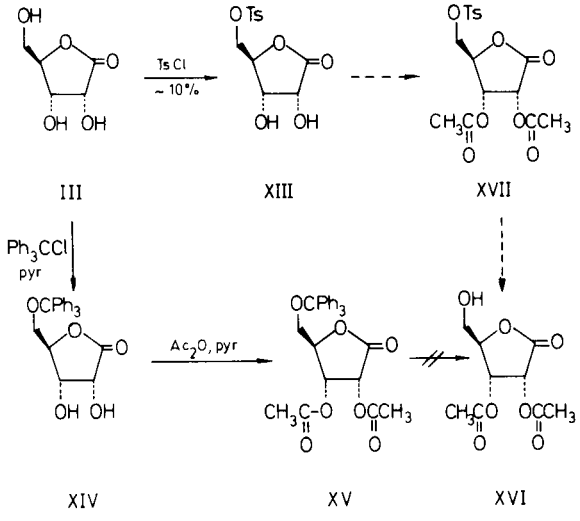
The optimal conditions (3 equivalents of cuprate, $-20°$, 2 hours) were the same as those found for the corresponding reaction of the tosylate IX, but the best yield obtained was only 30%. Since more simple systems give higher yields for their reaction with cuprates (*e.g.* see Scheme 2, arrow **a** for the synthesis of IIc) we conclude that not only the acidity of the orthoester proton is a negative factor but also the steric hindrance due to the rigidity of the bicyclic systems that we were using.

Thus, encouraged by the successful alkylation of the tosylate VII, we decided to explore other alternative routes for the chiral lactones of the type I and II, and, at the same time, to study the reactivity of some other non-bicyclic derivatives of D-ribonolactone, III, as well as derivatives of deoxy-D-ribonolactone, XVIII.

One of these derivatives would be the tosylate diacetate XVII. This compound cannot be synthesized through the intermediate XIII, from monotosylation of III, since it is known that under the reaction conditions, the hydroxyl group at C-2 also reacts [16,17]. We expected to prepare XVII *via* the trityl derivative XIV [14], which was acetyla-

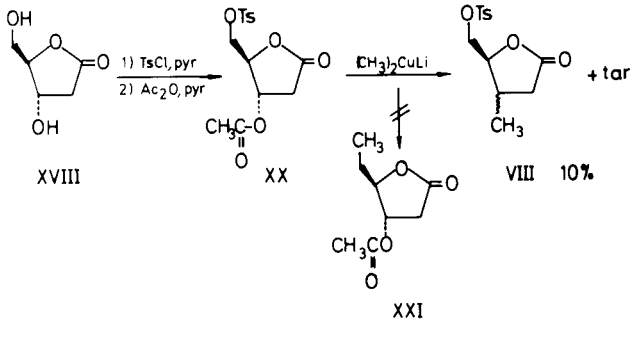
ted to give XV (Scheme 3).

Scheme 3



Nevertheless, the acetoxy groups were not compatible with the acidic conditions required to hydrolyze the trityl ether in XV. Moreover, this ether remained unaltered under catalytic hydrogenation making not possible the obtention of XVI and XVII by this way.

Scheme 4

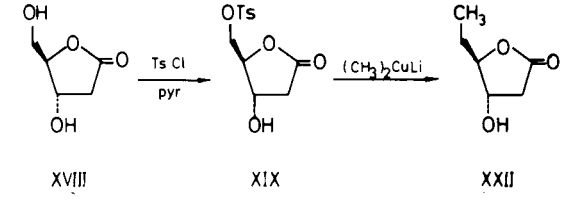


Derivatives of 2-deoxy-D-ribonolactone (although much more expensive than D-ribonolactone) could fit in the bond formation sequence (Scheme 4): alkylation before double bond formation. In this direction the tosylate XX was prepared from XVIII. However, reaction of XX with lithium dimethyl cuprate did not give the desired product XXI. Instead, a complex mixture was obtained, identifying after column chromatography, recovered starting material and the tosylate VIII resulting from Michael addition to the butenolide V, formed from XX by elimination of acetic acid.

Other protections of the secondary hydroxyl group of XVIII, as, for instance, a tetrahydropyranyl ether, also led to elimination under the reaction conditions.

Finally, we tried the reaction of the tosylate XIX with lithium dimethyl cuprate, obtaining the hydroxy lactone XXII in 31% yield, together with much polymeric material (Scheme 5).

Scheme 5



We can conclude that the sequence depicted in Scheme 2, arrow **b**, with the orthoesters Xb and Xc as key intermediates, is the method of choice that provides an easy and versatile route to optically active γ-alkyl butenolides I and butanolides II, in four and five steps, respectively, from commercially available D-ribonolactone.

EXPERIMENTAL

Melting points have been determined on a Kofler hot stage and are uncorrected. Optical rotations were obtained on a Bellingham-Stanley P-10 polarimeter. Distillation of small amounts were effected on a rotational distillator Buchi, model KRV 65/30 (only external or oven temperature given). The 70 eV electron impact or chemical ionization (isobutane) mass spectra were recorded with a Hewlett-Packard apparatus, model 5985 B. The infrared spectra were recorded on a Perkin-Elmer Spectrophotometer, model 720. The 80 MHz pmr spectra and 20 MHz cmr spectra were recorded on a Brucker Spectrometer, model WP 80 SY; chemical shifts are given in parts per million relative to TMS (δ scale).

(+)-*(S)*-5-*p*-Toluenesulfonyloxymethyldihydro-2(3*H*)-furanone (VII).

The tosylate VII was prepared according to the method described by Silverstein [12], in 70% yield, mp 85-86°, $[\alpha]_D^{26}$ +42.3° (c = 2.74, methylene chloride) (lit [18] mp 84-85°, $[\alpha]_D^{23}$ +46.2 (c = 1.63, chloroform)); the ir, pmr and ms spectral data were in agreement with those reported by Silverstein; cmr (deuteriochloroform): 21.4, 23.3, 27.7, 70.0, 76.4, 127.8, 129.9, 132.4, 145.2, 175.8.

5-Deoxy-2,3-*O*-ethoxymethylene-5-methyl-γ-D-ribonolactone (Xb).

To a stirred suspension of cuprous iodide (1.60 g, 8.38 mmoles) in anhydrous ether (25 ml) at −10° under argon was slowly added 10.5 ml (16.80 mmoles) of a 1.6 molar solution of methyllithium in anhydrous ether. After 30 minutes, a solution of tosylate IX (1 g, 2.79 mmoles) in anhydrous dimethoxyethane (5 ml) was added dropwise. After stirring 2 hours at −10° the mixture was hydrolyzed with saturated aqueous ammonium chloride (10 ml), stirred for 15 minutes to reach room temperature and then filtered. The layers were separated and the aqueous layer was extracted with three 15 ml portions of ethyl acetate. The combined organic layers were washed with saturated aqueous sodium chloride (10 ml) and dried over anhydrous sodium sulfate. The solvents were removed under reduced pressure to give 240 mg of a crude, which chromatographed through silica gel (1:1 methylene chloride-hexane as eluent) afforded pure Xb (202 mg, 36% yield) as a liquid, bp 95°/0.4 torr; ir (film): 1780 cm^{-1} (C=O); pmr (deuteriochloroform): 0.95 (t, 3H, J = 7.0 Hz), 1.10 (t,

3H, J = 6.8 Hz), 1.62 and 1.71 (two q, 2H, J = 7.0 Hz), 3.53 (q, 2H, J = 6.8 Hz), 4.43 (d, 1H, J = 6.8 Hz), 4.56 (t, 1H, J = 7.0 Hz), 4.72 (d, 1H, J = 6.8 Hz), 5.88 (s, 1H); cmr (deuteriochloroform): 8.2, 14.4, 27.1, 61.0, 73.1, 78.9, 85.9, 116.3, 172.6; ms: (chemical ionization) 203 ($M^+ + 1$, 42), 157 ($M^+ - EtO$, 100).

Anal. Calcd. for $C_9H_{14}O_5$: C, 53.46; H, 6.98. Found: C, 53.42; H, 7.13.

The following two compounds were prepared in a similar manner.

5-Deoxy-2,3-*O*-ethoxymethylene-5-butyl-γ-D-ribonolactone (Xc).

Liquid Xb was obtained in 25% yield by reaction at −20° for 2 hours of tosylate IX (0.3 g, 1.68 mmoles) and lithium dibutyl cuprate, prepared from cuprous iodide (0.32 g, 1.68 mmoles) and butyllithium (2.1 ml of a 1.6 molar solution in hexane, 3.36 mmoles), bp 100°/0.5 torr; ir (film): 1780 cm^{-1} (C=O); pmr (deuteriochloroform): 0.68-1.76 (complex absorption, 14H), 3.51 (q, 2H, J = 7.0 Hz), 4.42 (d, 1H, J = 6.8 Hz), 4.60 (t, 1H, J = 7.0 Hz), 4.72 (d, 1H, J = 6.8 Hz), 5.87 (s, 1H); cmr (deuteriochloroform): 13.7, 14.4, 22.3, 24.2, 31.2, 34.1, 61.1, 73.1, 79.3, 84.9, 116.3, 172.6; ms: (chemical ionization) 245 ($M^+ + 1$, 3.5), 199 ($M^+ - EtO$, 100).

Anal. Calcd. for $C_{12}H_{20}O_5$: C, 59.00; H, 8.25. Found: C, 59.40; H, 8.69.

(−)-5-Deoxy-2,3-*O*-isopropylidene-5-methyl-γ-D-ribonolactone (XII).

Liquid XII was obtained in 30% yield upon reaction at −20° for 2 hours of tosylate XI and lithium dimethylcuprate, prepared from cuprous idodide (1.34 g, 7 mmoles) and methyllithium (8.8 ml, of a 1.6 molar solution in ether, 14.0 mmoles), bp 102°/0.6 torr, $[\alpha]_D^{20}$ −51.4° (c = 2.76, methylene chloride); ir (film): 1786 cm^{-1} (C=O); pmr (deuteriochloroform): 1.02 (t, 3H, J = 7.1 Hz), 1.38 (s, 3H), 1.47 (s, 3H), 1.51-1.94 (complex absorption, 2H), 4.49 (t, 1H, J = 7 Hz), 4.56 (d, 1H, J = 5.9 Hz), 4.76 (d, 1H, J = 5.9 Hz); cmr (deuteriochloroform): 8.8, 25.4, 26.52, 26.56, 74.7, 79.0, 84.0, 113.5, 173.5; ms: 187 ($M^+ + 1$, 2.8), 171 (100), 85 (30.4), 59 (31.0), 43 (55.6).

Anal. Calcd. for $C_9H_{14}O_4$: C, 58.05; H, 7.58. Found: C, 57.70; H, 7.65.

(−)-*(R)*-5-Ethyl-2(5*H*)-furanone (Ib).

The orthoester Xb (78 mg, 0.39 mmole) was heated in a sealed tube at 220° for 35 minutes. Subsequent chromatography through silica gel (3:2 methylene chloride-hexane as eluent) afforded 28 mg of liquid Ib (65% yield), bp 90°/12 torr, $[\alpha]_D^{20}$ −97.6° (c = 2.08, methylene chloride) (lit [9]: bp 77°/1 torr; $[\alpha]_D^{23}$ −95° (liquid, longitude = 1 dm)); ir (film): 1760 (C=O), 1600 cm^{-1} (C=C); pmr (deuteriochloroform): 1.0 (t, 3H, J = 7.0 Hz), 1.59-2.01 (complex absorption, 2H), 5.03 (two pairs of dd, 1 H, J = J′ = 6.0, J″ = 2.0, J‴ = 1.5 Hz), 6.11 (dd, 1H, J = 5,7, J′ = 2.0 Hz), 7.54 (dd, 1H, J = 5.7, J′ = 1.5 Hz); cmr (deuteriochloroform): 8.5, 25.9, 84.0, 121.1, 156.0, 172.7; ms: 112 (M^+, 13.2), 84 (19.3), 83 (100), 75 (2.9), 57 (15.1), 55 (45.4), 41 (5.4), 39 (7.0).

(−)-*(R)*-5-Pentyl-2(5*H*)-furanone (Ic).

A 10 ml flask containing Xc (125 mg, 0.51 mmole) was connected to a rotary microdistillation apparatus and heated at 222°/atmospheric pressure to give 74 mg of a crude which was distillated at 100°/12 torr to yield Ic (54 mg, 68% yield), $[\alpha]_D^{20}$ −83.3 (c = 3.6, methylene chloride); ir (film): 1750 (C=O), 1600 cm^{-1} (C=C); pmr (deuteriochloroform): 0.72-1.89 (complex absorption, 11H), 5.06 (m, 1H), 6.10 (dd, 1H, J = 5.4, J′ = 1.8 Hz), 7.48 (dd, 1H, J = 5.4, J′ = 1.5 Hz); cmr (deuteriochloroform): 13.7, 22.2, 24.5, 31.3, 33.1, 83.3, 121.3, 156.2, 172.8; ms: 154 (M^+, 42.1), 125 (21.5), 111 (88.4), 98 (100), 83 (22.6), 70 (32.9), 55 (57.9), 41 (10.9).

Anal. Calcd. for $C_9H_{14}O_2$: C, 70.10; H, 9.15. Found: C, 70.21; H, 9.20.

(+)-*(R)*-5-Ethyldihydro-2(3*H*)-furanone (IIb).

From VII.

Butanolide IIb was obtained in 75% yield upon reaction of tosylate VII (0.40 g, 1.48 mmoles) and lithium dimethyl cuprate (3 equivalents), prepared as described above, 3 hours at −20°, bp 96°/12 torr, $[\alpha]_D^{20}$ +50.5° (c = 2, methylene chloride) (lit [12]), $[\alpha]_D^{20}$ +53.2° (c = 1, methanol); ir (film): 1770 cm^{-1} (C=O); pmr (deuteriochloroform): 1.0 (t, 3H, J = 7.1 Hz), 1.50-2.68 (complex absorption, 6H), 4.46 (m, 1H); cmr (deuteriochloroform): 9.0, 27.2, 28.3, 28.6, 81.9, 176.8; ms: 114 (M^+, 3.3), 86 (7.7), 85 (100), 70 (9.8), 57 (9.7), 56 (8.6), 55 (7.4), 39 (3.1).

From Ib.

The butenolide Ib (103 mg, 0.92 mmole) in 10 ml of ethyl acetate was hydrogenated at atmospheric pressure in the presence of 10% palladium on carbon (11 mg) as catalyst. The solvent was removed *in vacuo* at reduced pressure and the residue was filtered through silica gel to give IIb (101 mg, 96% yield).

The following compound was prepared in a similar manner.

(+)-*(R)*-5-Pentyldihydro-2(3*H*)-furanone (IIc).

This product was obtained in 95% yield, bp 108°/12 torr, $[\alpha]_D^{20}$ +44.6 (c = 2.4 methylene chloride) (lit [14]), $[\alpha]_D^{20}$ +47.2 (c = 1, methanol); ir (film): 1770 cm^{-1} (C=O); pmr (deuteriochloroform): 0.82-2.6 (complex absorption, 15H), 4.50 (m, 1H); cmr (deuteriochloroform): 13.5, 22.1, 24.6, 27.7, 28.5, 31.2, 35.3, 80.6, 176.7; ms: 138 (M^+, 1.4), 85 (100), 55 (9.5).

(+)-2,3-*O*-Diacetyl-5-*O*-triphenylmethyl-γ-D-ribonolactone (XV).

To a stirred and ice-cooled solution of XIV (4 g, 10.23 mmoles) (prepared according to ref [14]) in 35 ml of anhydrous pyridine, acetyl chloride (3.22 g, 41.0 mmoles) was added dropwise. The mixture was stirred at room temperature for 16 hours and then filtered. Pyridine and unreacted acetyl chloride were evaporated at reduced pressure and the residue was dissolved in chloroform and washed with 5% hydrochloric acid and dried over anhydrous sodium sulfate. The solvent was removed *in vacuo* and the crude was chromatographed through silica gel (methylene chloride-hexane as eluent) to afford 3.65 g of pure XV (75% yield), mp 107-109° (from diethyl ether), $[\alpha]_D^{20}$ +19.2 (c = 5.74, methylene chloride); ir (deuteriochloroform): 3060 (aromatic), 1800 (lactone), 1760 (acetate), 1490, 1450, 1385, 1240, 1095, 1000 cm^{-1} (aromatic and C-O); pmr (deuteriochloroform): 2.07 (s, 3H), 2.14 (s, 3H), 3.32 (dd, 1H, J = 11.4, J′ = 2.4 Hz), 3.69 (dd, 1H, J = 11.4, J′ = 2.8 Hz), 4.50 (m, 1H), 5.38 (d, 1H, J = 6.3 Hz), 6.11 (d, 1H, J = 6.3 Hz), 7.32 (complex absorption, 15H); cmr (deuteriochloroform): 20.0, 20.3, 62.8, 67.2, 70.8, 82.1, 88.3, 127.5, 128.1, 128.7, 142.9, 168.9, 169.5, 170.8; ms: 474 (M^+, 4), 243 (67.5), 215 (22.5), 165 (100), 105 (32.2), 83 (14.5), 57 (16).

Anal. Calcd. for $C_{28}H_{26}O_7$: C, 70.87; H, 5.52. Found: C, 70.73; H, 5.48.

(+)-2-Deoxy-5-*O*-*p*-toluenesulfonyl-γ-D-ribonolactone (XIX).

To a stirred solution of XVIII (0.34 g, 2.58 mmoles) in 8 ml of anhydrous pyridine, cooled at −15°, *p*-toluenesulfonyl chloride (0.54 g, 2.83 mmoles) was added in one single portion. The mixture was stirred at −5° for 6 hours. Then 1 ml of water was added and this mixture was allowed to stand for 5 minutes. The resulting solution was added dropwise over 150 ml of ice-water with simultaneous and vigorous stirring. The aqueous solution was extracted with three 35 ml portions of ethyl acetate and the organic extracts were concentrated, washed with 5% hydrochloric acid and dried over anhydrous sodium sulfate. The solvent was removed at reduced pressure to give 0.51 g of a crude which was chromatographed through 15 g of silica gel (mixtures of methylene chloride-hexane (4:1) and methylene chloride-ether (3:1) were used as eluents) to afford 0.42 g of XIX (57% yield), mp 56-58° (from methylene chloride-ether-pentane), $[\alpha]_D^{20}$ +39.6° (c = 5.3, methylene chloride); ir (chloroform): 3650-3200 (broad band), 1780 (C=O), 1600, 1360, 1170, 1090 cm^{-1} (aromatic and C-O); pmr (deuteriochloroform): 2.44 (s, 3H), 2.46 (dd, 1H, J = 18.2, J′ = 3.8 Hz), 2.89 (dd, 1H, J = 18.2, J′ = 6.4 Hz), 3.46 (d, 1H, J = 4.4 Hz), 4.22 (d, 2H, J = 3.0 Hz), 5.51 (m, 2H), 7.36 (d, 2H, J = 8.3), 7.76 (d, 2H, J = 8.3 Hz); cmr (deuteriochloroform): 21.7, 37.8, 68.3, 68.5, 84.2, 128.0, 130.3, 132.2, 145.8, 175.0; ms: 286 (M^+, 8.6), 222 (36.9), 155 (83.2), 101 (38.1), 91 (100), 83 (17.1), 65 (28.6).

Anal. Calcd. for $C_{12}H_{14}O_6S$: C, 50.40; H, 4.93; S, 11.21. Found: C, 50.54; H, 4.86; S, 11.44.

(+)-2-Deoxy-3-*O*-acetyl-5-*O*-*p*-toluenesulfonyl-γ-D-ribonolactone (XX).

To a solution of XIX (0.15 g, 0.53 mmole) in 7 ml of anhydrous pyridine, acetic anhydride (0.55 g, 5.3 mmoles) was added and the mixture was stirred at room temperature overnight, then poured with stirring into

100 ml of ice-water and the resulting solution was extracted with three 25 ml portions of chloroform. The combined organic layers were concentrated, washed with 5% hydrochloric acid and dried over anhydrous sodium sulfate. The solvent was removed at reduced pressure to give 180 mg of a crude which chromatographed through 10 g of silica gel (methylene chloride-hexane as eluent) afforded 150 mg of XX (86% yield), mp 77-79° (from ether), $[\alpha]_D^{20}$ +8.47 (c = 6.26, methylene (chloride); ir (potassium bromide): 1780 (lactone), 1725 cm^{-1} (acetate); pmr (deuteriochloroform): 2.08 (s, 3H), 2.45 (s, 3H), 2.54 (dd, 1H, J = 18.8, J' = 2.4 Hz), 3.01 (dd, 1H, J = 18.8, J' = 7.2 Hz), 4.20 (dd, 1H, J = 11.2, J' = 2.9 Hz), 4.38 (dd, 1H, J = 11.2, J' = 2.8 Hz), 4.60 (m, 1H), 5.25 (a pair of dd, 1H, J = 7.2, J' = 2.4, J'' = 1.8 Hz), 7.37 (d, 2H, J = 8.4 Hz), 7.77 (d, 2H, J = 8.4 Hz); cmr (deuteriochloroform): 20.4, 21.4, 34.4, 68.2, 70.7, 81.5, 127.8, 130.0, 132.2, 145.4, 170.0, 173.0; ms: 328 (M^+, 37.5), 222 (10), 204 (42.5), 155 (93.7), 143 (80), 91 (100), 83 (62.5), 65 (38.8), 43 (80).

Anal. Calcd. for $C_{14}H_{16}O_7S$: C, 51.27; H, 4.92; S, 9.78. Found: C, 51.37; H, 4.97; S, 9.76.

(+)-2,5-Dideoxy-5-methyl-γ-D-ribonolactone (XXII).

This product was prepared following the method described above for compound Xb. Thus, 85 mg of chromatographed liquid XXII (31% yield) was obtained from cuprous iodide (1.40 g, 7.34 mmoles), methyllithium (9.2 ml of a 1.6 molar solution in ether, 14.72 mmoles) and tosylate XIX (0.6 g, 2.10 mmoles), bp 80°/0.1 torr, $[\alpha]_D^{20}$ +26.8 (c = 2.46, methylene chloride); ir (film): 3700-3100 (broad band), 1770 cm^{-1}; pmr (deuteriochloroform): 1.0 (3H, t, J = 6.1 Hz), 1.46-2.09 (complex absorption, 3H), 2.45 (dd, 1H, J = 17.9, J' = 4.0 Hz), 2.85 (dd, 1H, J = 17.8, J' = 6.4 Hz), 4.13-4.38 (complex absorption, 2H); cmr (deuteriochloroform): 9.3, 26.0, 37.7, 71.0, 89.3, 175.6; ms (chemical ionization): 131 (M^+ + 1, 100), 113 (M^+ − 17); ms: (electron impact) 102 (70.9), 101 (26.8), 83 (32.5), 58 (25.4), 59 (100), 57 (53.9), 44 (78.6), 43 (63.0).

Anal. Calcd. for $C_6H_{10}O_3$: C, 55.37; H, 7.74. Found: C, 55.55; H, 8.15.

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