# 182. Synthesis of Naphtho[2,3-*b*]pyrandiones: (–)-Cryptosporin

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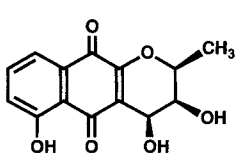
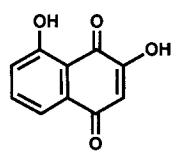
A new method for the synthesis of naphtho[2,3-*b*]pyrandiones from sulfonyllactones and 1-nitroglycals is presented. Thus, the sulfonyllactone **6** reacted with the 1-nitroglycal **7** in the presence of LDA at room temperature to give the naphthopyrandione **9** in high yields (*Scheme 1*). Reaction at a lower temperature led to the (intermediate) *Michael*-addition products **8**. The sulfonyllactone **4** and the 1-nitroglycal **5** were prepared for the synthesis of the naphthopyrandione **18** (*Scheme 2*). The base-promoted condensation of **4** and **5** gave **17**, which was deprotected to give **18**, the enantiomer of the fungal metabolite (+)-cryptosporin **1**.

**Introduction.** – In 1973, *Closse* and *Sigg* [1] proposed structure **1** for (+)-cryptosporin, a metabolite of the fungus *Cryptospora pinicola* L. with week inhibitory activity on *Gram*-positive bacteria. The relative configuration and the constitution of cryptosporin were deduced from the $^1$H-NMR spectra and from the results of a chemical degradation, correlating cryptosporin with a known dihydroxynaphthoquinone [2], the structure of which, however, was only recently revised and shown to correspond to **2** [3]. Hence, cryptosporin must possess the constitution and relative configuration indicated in formula **3**. The absolute configuration was established on the basis of the *Cotton* effect of its tribenzoate. The validity of this deduction has been questioned [4]. A synthesis by *Krohn et al.* [5] of racemic 6-deoxycryptosporin did not prove the structure of cryptosporin.




**1**

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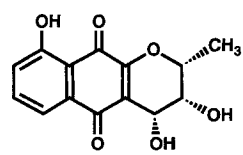


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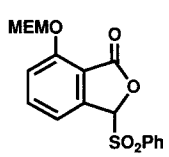
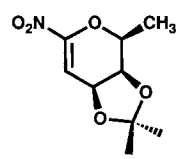



**4**



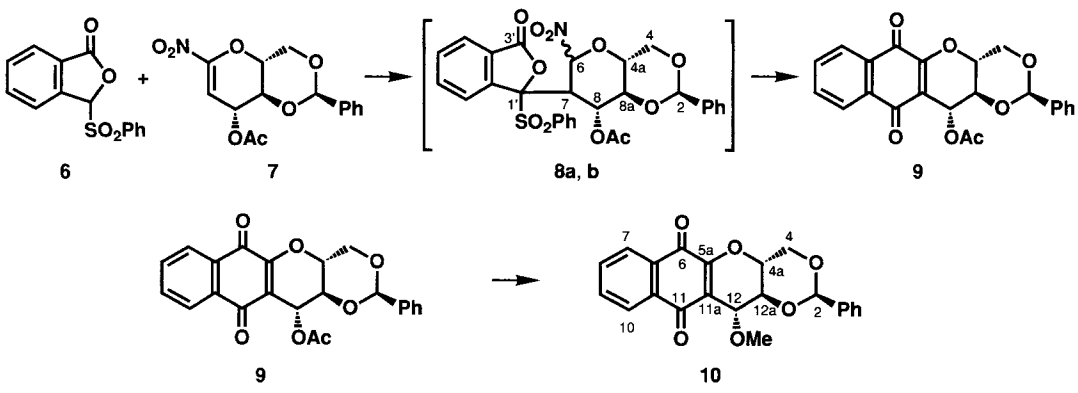

**5**

Cryptosporin belongs to the rather small class of naturally occurring naphtho-[2,3-*b*]pyrandiones[1]). *Tatsuta et al.* have described a synthesis of isomeric naphtho-[2,3-*c*]pyrandiones from carbohydrate-derived enones [11] (*cf.* [12]). In a similar fashion, we envisioned a general, regio- and enantiospecific synthesis of naphtho[2,3-*b*]pyrandiones from sulfonylphthalides such as **4** and from carbohydrate-derived $\alpha,\beta$-unsaturated nitro compounds (1-nitroglycals) such as **5**.

Quite a variety of differently substituted sulfonyllactones of the type **4** are known [13]. Their use for the regiospecific synthesis particularly of anthraquinones[2]) has been well established by *Hauser et al.* [13a,b,f][15]. A fair number of 1-nitroglycals are known [16], but they have so far not been used for the formation of C–C bonds at C(2).

**Results.** – To investigate the reactivity of 1-nitroglycals towards sulfonyllactones, we examined the required base-catalyzed sequence of *Michael*-addition, *C*-acylation, and double $\beta$-elimination using the known, easily available compounds **6** [13a] and **7** [16] (*Scheme 1*). In the presence of a slight excess of lithium diisopropylamide (LDA) at –70 to 40°, these compounds gave **9** in 89% yield. At a somewhat lower temperature (–70 to 20°), the reaction between **6** and **7** yielded at least four compounds. Chromatography gave some **9** and mixtures of two addition compounds **8a** and **8b** in variable proportions.

*Scheme 1*




The UV spectrum of **9** shows typical naphthoquinone [17] absorptions at 333 (log $\varepsilon$ 3.46), 278 (4.04), 249 (4.26), and 243 (4.25) nm. In the IR spectra, bands at 1683, 1660, and 1613 $cm^{-1}$ are again typical for quinones. The $^1$H-NMR spectra show the expected signals, in particular the presence of the AcO group (Ac at 2.15 ppm; H–C(12) at 6.50 ppm (*d*, *J* = 8.1 Hz)), the benzylidene moiety (5 arom. H at 7.52–7.35 ppm; H–C(2) at 5.64 ppm (*s*)) and the *ortho*-disubstituted benzene ring (2 arom. H at 8.15–8.06 and 2 arom. H at 7.81–7.69 ppm). In the $^{13}$C-NMR spectrum of **9**, the signals of the naphthoquinone C=O groups are found at 182.0 and 178.7 ppm.

The IR-spectra of **8a** and **8b** show $NO_2$ bands at 1566 and 1568 $cm^{-1}$ (as recorded of a 4:1 and a 2:3 mixture of **8a** and **8b**, respectively). The MS of a 4:1 mixture of **8a** and **8b** shows a peak at *m/z* = 549 ($M^+ - NO_2$). The $^1$H-NMR-spectra of **8a** and **8b** ($CDCl_3$ and ($D_6$)benzene) show similar coupling constants, particularly for

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[1]) Other members of this class are, *e.g.* xyloidon [6], $\alpha$-caryopteron [7], 4,9-dihydroxy-$\alpha$-lapachon [8], annulin B [9], gunacin [10].

[2]) For an early example of a regioselective synthesis of hydroxyanthraquinones, see [14].

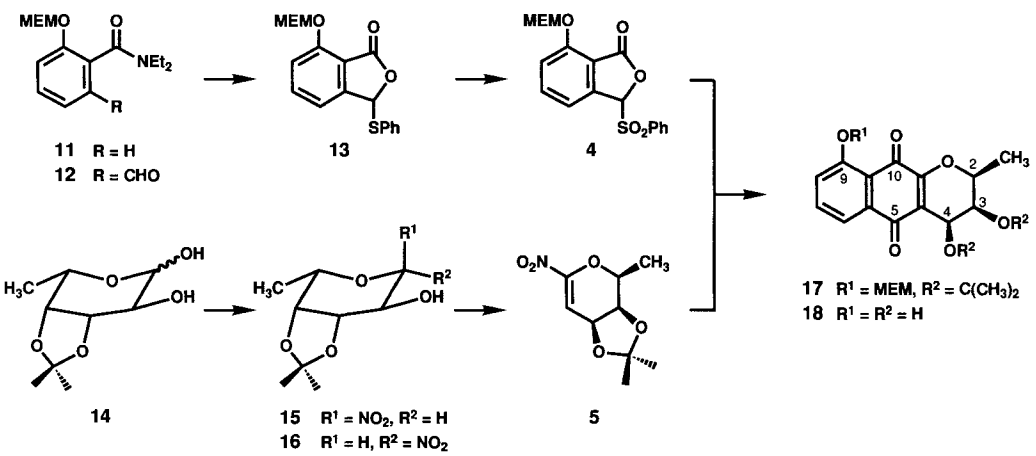
H–C(6–8), consistent with a D-*manno*-configuration ($J(7,8)$ = 4.1 and 6.5 Hz and $J(6,7)$ = 1.2 and 0.9 Hz, $CDCl_3$), and with the assumption that **8a** and **8b** are anomers. The chemical-shift differences between the H–C(6–8) signals are quite large and the question, if these addition products are also epimeric at C(1') remains open. The $^{13}$C-NMR spectra are consistent with the proposed structure.

Attempted base-catalyzed deacetylation of **9** (NaOMe, MeOH), only gave the crystalline methyl ether **10**, presumably as the result of a reaction sequence initiated by β-addition of methoxide at C(5a) and leading, *via* a sequence of β-elimination of acetate, β-addition of methoxide at C(12), and β-elimination of the originally introduced MeO residue, to **10**.

In the $^1$H-NMR spectrum of **10**, one finds the MeO signal at 3.80 ppm and the H–C(12) signal at 4.68 ppm (*d*, $J$ = 7.3 Hz). The coupling constants $J(4a,12a)$ of **10** (10.1 Hz), and $J(4a,12a)$ of **9** (10.2 Hz) are also quite similar, evidencing the *arabino*-configuration.

The direct and high-yield synthesis of **9** augured well for the preparation of cryptosporin from the sulfonyllactone **4** and the 1-nitroglycal **5**, derived from the more easily available L-enantiomer of fucose. We chose the 2-methoxyethoxy substituted analogue **4** of the corresponding known methyl ether [13e,h] to facilitate the final deprotection. For its synthesis (*Scheme 2*), the known *N,N*-diethyl-2-methoxybenzamide [19] was transformed into its protected analogue **11** (MEMO = (2-methoxyethoxy)methoxy). Deprotonation of **11** (*s*-BuLi; *N,N,N',N'*-tetramethylethylenediamine (TMEDA)) and formylation (DMF) gave the aldehyde **12**, which was treated with PhSH at 80–85° to yield the (phenylthio)lactone **13** (*cf.* [20]). Peracid oxidation [21] gave the desired lactone **4**.

*Scheme 2*




The known 3,4-*O*-isopropylidene-L-fucose **14** [22] was transformed in the standard way [23] (formation of the oximes, treatment of the oximes with *p*-nitrobenzaldehyde, and ozonolysis of the resulting nitrones) and in good yields into a mixture of the crystalline, anomeric 1-deoxy-1-nitroaldoses **15** and **16**. Acetylation of **15/16** and β-elimination afforded the crystalline nitrofucal **5** again in high yields.

The IR spectrum of the anomers **15** and **16** show $NO_2$ bands at 1568 and 1570 $cm^{-1}$, respectively [18]. In the $^1$H-NMR spectra, the H–C(1) *d* of **15** is found at 5.69 ppm ($J$(1,2) = 4.4 Hz) and H–C(1) of **16** at 5.24 ppm ($J$(1,2) = 5.8 Hz); the H–C(2) signals occur at 4.73 ($J$(2,3) = 3.4 Hz) and at 4.30 ppm ($J$(2,3) = 5.4 Hz), respectively. The values of these and of the other coupling constants of the pyranose-ring protons ($J$(3,4) = 7.6 (**15**) and 6.3 Hz (**16**), and $J$(4,5) = 1.7 (**15**) and 2.2 Hz (**16**)) indicate the deviation from a chair conformation for both anomers. The $^{13}$C(1) signals appear at 103.4 and at 104.4 ppm, respectively.

The nitrofucal **5** is characterized by an IR spectrum with typical bands at 1674 (C=C) and at 1548 $cm^{-1}$ ($NO_2$) [16]. In the $^1$H NMR spectrum, the H–C(2) signal is found at 6.21 ppm (*dd*, $J$ = 3.6 and 1.0 Hz), showing a long-range coupling. The coupling constants and the values of $J$(3,4) = 5.8 Hz and $J$(4,5) = 1.2 Hz agree quite well with a half chair conformation, similarly to what has been found for analogous compounds [16].

Reaction of **5** with the sulfonyllactone **4** in the presence of LDA yielded the protected naphthoquinone **17** (65%), which was deprotected (62%) to yield a compound **18** which proved to be the enantiomer of cryptosporin, showing the same m.p., IR, $^1$H-NMR, and $^{13}$C-NMR spectra as cryptosporin, but possessing opposite chiroptical properties[3]) (see the *Fig.*). Its mixed m.p.with authentic cryptosporin[4]) showed a strong depression. Hence, cryptosporin must possess structure **3**. Very recently [25], *Gupta* and *Franck* reported a synthesis of (–)-cryptosporin from L-fucal using the *Bradsher* cycloaddition as a key step and reaching the same conclusion as to the structure of cryptosporin. The methods of *Gupta* and *Franck* and the one presented here constitute two different and apparently general ways for the synthesis of enantiomerically pure pyrano[2,3-*b*]naphthoquinones.

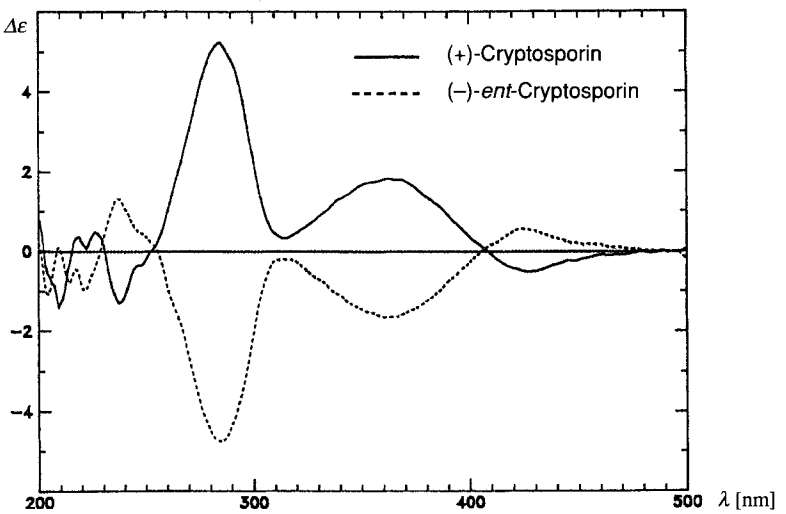
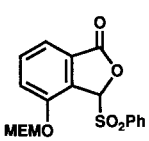



Figure. *CD Spectra of (+)-cryptosporin* **1** *and (–)-***18**

We thank the *Swiss National Science Foundation* and *Sandoz AG*, Basle, for generous support.

[3]) Similarly, the reaction of **5** with the isomeric sulfonyllactone **19** gave, after deprotection, *ent*-isocryptosporin **1** (m.p. 179–180°, $[\alpha]_D$ = –261.7 (*c* = 0.61, acetone)) [24].




**19**

[4]) We thank Dr. *Pietro Bollinger*, *Sandoz AG*, Basle, for a sample of cryptosporin.

## Experimental Part

*General.* See [26]. Normal workup implies extraction (3 ×) with the indicated solvent, washing of the org. phase as indicated, finally with brine, drying the org. phase ($MgSO_4$), and evaporation of the solvent at or below 40° *in vacuo*. TLC: 0.25-mm precoated silica-gel plates (*Merck*, Kieselgel *60* $F_{254}$). Flash chromatography (FC): silica gel *Merck 60* (70–230 mesh). Medium-pressure liquid chromatography (MPLC): silica gel *Merck 60* (230–400 mesh). UV spectra ($\lambda_{max}$ in nm (log $\varepsilon$)). CD spectra ($\lambda_{max}$ in nm ($\Delta\varepsilon$)). $^1$H- and $^{13}$C-NMR spectra: chemical shifts in ppm rel. to TMS.

*1,6-Dideoxy-3,4-*O*-isopropylidene-1-nitro-α-*L*-galactopyranose* (**15**) *and 1,6-Dideoxy-3,4-*O*-isopropylidene-1-nitro-β-*L*-galactopyranose* (**16**). To a soln. of NaOMe in 500 ml of MeOH (from 5.8 g Na) were added 15.5 g of $NH_2OH \cdot HCl$ and 22.7 g (0.111 mol) of **14**. The mixture was heated for 4 h to 50–53°. Evaporation of the solvent and normal workup (AcOEt) gave 7.15 g (31%) of **14** in the org. phase. The aq. phases were evaporated, EtOH (2 × 60 ml) was added and evaporated, and the residue treated with 10 g of $MgSO_4$ and extracted with AcOEt (3 × 100 ml): 16.1 g (66%; 96% based on recovered starting mat.) of *3,4-*O*-isopropylidene-*L*-fucose oximes* as an oil.

A mixture of 2.35 g (10.72 mmol) of these oximes, 2.09 g of *p*-nitrobenzaldehyde, 21.7 mg of TsOH · $H_2O$, and 16.8 g of $MgSO_4$ in 60 ml of $CH_2Cl_2$ was stirred at r.t. for 4 h and filtered through *Celite*. $O_3$ was passed through the filtrate at –78° for 45 min and then replaced by $N_2$, while the mixture was allowed to reach r.t. Normal workup ($CHCl_3$; $NaHSO_3$) afforded 2.37 g of a mixture. FC (hexane/AcOEt 7:3 → 6:4) gave 1.15 g (46%) of **15** and 0.57 g (23%) of **16**.

*Data of* **15**: M.p. 89–91° (hexane/AcOEt 8:2). $[\alpha]_D^{25}$ = +39.2 (*c* = 1.31, $CHCl_3$). IR ($CHCl_3$): 3610*m*, 3500*w* (br.), 2995*m*, 2945*w*, 2920*w* (sh), 1568*s*, 1563*s* (sh), 1542*w* (sh), 1447*w*, 1384*m* (sh), 1376*s*, 1352*m*, 1341*m*, 1314*w* (sh), 1278*w* (sh), 1250*m* (br.), 1180*m*, 1155*m*, 1123*m*, 1098*m*, 1077*s*, 1052*m*, 1013*s*, 972*w*, 960*w*, 917*w*, 883*w* (sh), 870*m*. $^1$H-NMR (200 MHz, $CDCl_3$): 5.69 (*d*, *J* = 4.4, H–C(1)); 4.73 (br. *q*, with $D_2O$: '*t*', *J* ≈ 3.9, H–C(2)); 4.59 (*dd*, *J* = 7.6, 3.4, H–C(3)); 4.40 (*qd*, *J* = 6.6, 1.7, H–C(5)); 4.20 (*dd*, *J* = 7.5, 1.7, H–C(4)); 3.00 (br. *d*, *J* = 5.7, exchangeable with $D_2O$, OH); 1.46 (*s*, 3 H); 1.37 (*s*, 3 H); 1.36 (*d*, *J* = 6.4, 3 H–C(6)). $^{13}$C-NMR (50 MHz, $CDCl_3$): 110.6 (*s*); 103.4 (*d*); 74.2 (*d*); 73.6 (*d*); 69.5 (*d*); 64.4 (*d*); 26.0 (*q*); 24.8 (*q*); 15.5 (*q*). Anal. calc. for $C_9H_{15}NO_6$ (233.220): C 46.35, H 6.48, N 6.01; found: C 46.54, H 6.51, N 6.05.

*Data of* **16**: M.p. 107–109° (hexane/AcOEt 7:3). $[\alpha]_D^{25}$ = –51.4 (*c* = 1.32, $CHCl_3$). IR ($CHCl_3$): 3610*w*, 3430*w* (br.), 2995*m*, 2940*w*, 2890*w* (sh), 1570*s*, 1562*s* (sh), 1541*w* (sh), 1453*w*, 1446*w*, 1384*m*, 1372*s*, 1348*m* (sh), 1308*w*, 1289*w*, 1240*m* (br.), 1172*m*, 1148*s*, 1125*m*, 1092*s*, 1070*s*, 1040*m*, 1008*m*, 981*w*, 962*w*, 938*w*, 913*w*, 873*m*, 864*w* (sh). $^1$H-NMR (400 MHz, $CDCl_3$): 5.24 (*d*, *J* = 5.8, H–C(1)); 4.30 (*m*; with $D_2O$: '*t*', *J* ≈ 5.6, H–C(2)); 4.26 ('*t*', *J* ≈ 5.8, H–C(3)); 4.22 (*qd*, *J* = 6.6, 2.2, H–C(5)); 4.15 (*dd*, *J* = 6.3, 2.2, H–C(4)); 2.97 (br. *d*, *J* = 4.2, exchangeable with $D_2O$, OH); 1.49 (*s*, 3 H); 1.47 (*d*, *J* = 6.6, 3 H–C(6)); 1.35 (*s*, 3 H). $^{13}$C-NMR (50 MHz, $CDCl_3$): 110.4 (*s*); 104.4 (*d*); 76.1 (*d*); 74.6 (*d*); 70.9 (*d*); 69.8 (*d*); 26.6 (*q*); 25.0 (*q*); 16.3 (*q*). CI-MS: 218 (4), 203 (2), 188 (13), 187 (100, $M^+ - NO_2$), 169 (4), 157 (1), 129 (10), 113 (4), 101 (1), 85 (2), 71 (3). Anal. calc. for $C_9H_{15}NO_6$ (233.220): C 46.35, H 6.48, N 6.01; found: C 46.57, H 6.70, N 6.06.

*1,2,6-Trideoxy-3,4-*O*-isopropylidene-1-nitro-*L*-lyxo-hex-1-enopyranose* (**5**). To a soln. of 6.34 g (27.2 mmol) of **15/16** (7:3) in 40 ml of $CH_2Cl_2$ at 0° were added 6 ml of $Ac_2O$, 14 ml of pyridine and 4.3 mg of 4-(dimethylamino)pyridine. This mixture was kept at < 5° for 17 h, then poured into 20 ml of ice/$H_2O$ and worked up as usual ($CH_2Cl_2$, $NaHCO_3$), yielding 6.67 g (89%) of a mixture (IR: 1762*m*, 1572*s*, 1563*m*, 1547*m*). A soln. of this mixture in 100 ml of $CHCl_3$ was stirred over night at r.t. in presence of 17 g of *Amberlite IRA 93* ($OH^-$ form). The filtrate obtained from this mixture was evaporated. MPLC (hexane/AcOEt 7:3 → 4:6) gave 4.94 g (84% from **15/16**) of **5**. An anal. sample was sublimed at ≤ 40°, $3 \cdot 10^{-2}$ mbar. M.p. 75–76° (hexane/$Et_2O$ 3:2). $[\alpha]_D^{25}$ = –81.9 (*c* = 0.97, $CHCl_3$). IR ($CHCl_3$): 3110*w*, 3015*m*, 2995*w*, 2945*w*, 2900*w*, 1674*m*, 1603*w*, 1563*m* (sh), 1548*s*, 1524*w* (sh), 1457*w*, 1448*w*, 1383*m*, 1372*m*, 1350*m* (sh), 1338*s*, 1307*w*, 1292*m*, 1274*w*, 1225*s* (sh), 1205*s* (br.), 1166*m*, 1133*m*, 1103*m*, 1076*s*, 1067*m* (sh), 1032*m*, 1013*m*, 962*w*, 929*w*, 894*w*, 870*m*, 852*m*, 780*s* (br.), 720*s* (br.), 663*s*, 623*w*. $^1$H-NMR (200 MHz, $CDCl_3$): 6.21 (*dd*, *J* = 3.6, $^4J$(2,4) = 1.0, H–C(2)); 4.93 (*dd*, *J* = 5.8, 3.6, H–C(3)); 4.38 (*qd*, *J* = 6.6, 1.2, H–C(5)); 4.23 ('*dt*', *J* = 5.9, 1.2, H–C(4)); 1.63 (*d*, *J* = 6.7, 3 H–C(6)); 1.41 (*s*, 3 H); 1.40 (*s*, 3 H). $^{13}$C-NMR (50 MHz, $CDCl_3$): 153.5 (*s*); 111.2 (*s*); 100.1 (*d*); 76.4 (*d*); 74.3 (*d*); 69.5 (*d*); 27.9 (*q*); 26.2 (*q*); 16.9 (*q*). CI-MS (80°): 217 (5), 216 (51, $M^+ + 1$), 200 (25), 187 (4), 169 (4), 159 (8),158 (100), 127 (4), 112 (8), 111 (27), 99 (11), 88 (79). Anal. calc. for $C_9H_{13}NO_5$ (215.205): C 50.23, H 6.09, N 6.51; found: C 50.25, H 6.26, N 6.47.

*7-[(2-Methoxyethoxy)methoxy]-3-(phenylsulfonyl)isobenzofuran-1(3*H*)-one* (**4**). A soln. of 8 ml (83.0 mmol) of $BBr_3$ in 30 ml of $CH_2Cl_2$ was added, at –78° within 15 min, to a soln. of 10.36 g (50 mmol) N,N-*diethyl-2-methoxybenzamide* in 40 ml of $CH_2Cl_2$ (intensive coloration). The cooling bath was removed, the mixture was stirred for 14 h at r.t., cooled to 0°, slowly treated with 100 g of ice/$H_2O$, and then diluted with 40 ml of $CH_2Cl_2$. The org. phases were extracted with 3 × 60 ml of 1M NaOH. Neutralisation of the aq. phase

with 12 ml of conc. HCl at 0° and extraction with 3 × 50 ml of $Et_2O$ gave 8.74 g (45.2 mmol, 90%) of N,N-*diethyl-2-hydroxybenzamide*, which was treated at 0° with 5.2 ml (45.8 mmol) chloro(ethoxy)(methoxy)methane (MEM-Cl) in 100 ml of THF in the presence of 1.30 g of hexane-washed NaH. After 3 h at r.t., normal workup ($Et_2O$, 0.5M NaOH) gave 11.1 g (87%) of N,N-*diethyl-2-[(2-methoxyethoxy)methoxy]benzamide* (**11**) as an oil. A mixture of 11.0 g (39.1 mmol) of **11** in 120 ml of abs. THF, 6.5 ml (43.2 mmol) TMEDA and 31 ml of 1.4M *s*-BuLi in hexane (43.4 mmol) was stirred for 1 h at –78° and then treated with 10 ml of DMF. The cooling bath was removed and stirring was continued for 20 h at r.t., whereupon 40 ml of ice/$H_2O$ was added, followed by 16 ml of conc. HCl. Normal workup of the neutral mixture (AcOEt; 1M HCl, $H_2O$, 0.5M NaOH) gave 10.48 g of a product, which, upon MPLC ($CH_2Cl_2$/AcOEt/MeOH 49:49:2), gave 8.72 g (72%) of N,N-*diethyl-2-formyl-6-[(2-methoxyethoxy)methoxy]benzamide* (**12**). IR ($CHCl_3$): 3035*w* (sh), 2995*m*, 2940*w*, 2895*w*, 2885*w*, 2830*w*, 2750*w*, 1704*s*, 1689*w* (sh), 1628*s*, 1597*m*, 1583*w*, 1482*m*, 1464*m*, 1437*w*, 1397*w* (sh), 1383*w*, 1367*w*, 1349*w*, 1314*w*, 1286*m*, 1248*s*, 1205*s* (br.), 1162*m*, 1136*m* (sh), 1108*s*, 1082*m* (sh), 1048*m* (sh), 1028*m*, 998*w* (sh), 944*m*, 912*m*, 876*w*, 850*w*. $^1$H-NMR (200 MHz, $CDCl_3$): 9.99 (*s*, CHO); 7.59 (*dd*, *J* = 5.9, 2.9, 1 H); 7.51–7.44 (*m*, 2 H); 5.37–5.26 ('*AB*', 2 H); 3.85–3.80 (*m*, 2 H); 3.73–3.52 (*m*, 4 H); 3.37 (*s*, 3 H); 3.13 (*q*, *J* = 7.3, 2 H); 1.31 (*t*, *J* = 7.1, 3 H); 1.03 (*t*, *J* = 7.2, 3 H).

A mixture of 7.79 g (25.2 mmol) of **12** and 50 ml of PhSH was heated for 3 h to 80–85° and then evaporated at ≤ $10^{-2}$ mbar. Normal workup of the residue (AcOEt, 0.5M NaOH) gave 12.4 g of material, which, upon MPLC (hexane/AcOEt, 45:55), gave 3.70 g (42%) of *7-[(2-Methoxyethoxy)methoxy]-3-(phenylthio)isobenzofuran-1(3H)-one* (**13**). IR ($CHCl_3$): 3065*w* (sh), 3035*w* (sh), 3005*w*, 2930*w*, 2890*w*, 2825*w*, 1770*s*, 1614*m* (sh), 1608*s*, 1587*w*, 1486*s*, 1476*m* (sh), 1452*w*, 1442*w*, 1416*w*, 1368*w*, 1292*m*, 1267*m*, 1250*m*, 1205*m* (br.), 1159*s*, 1137*m* (sh), 1108*s*, 1078*m*, 1053*m*, 1020*s*, 962*s*, 946*s* (sh), 850*w*. $^1$H-NMR (200 MHz, ($D_6$)acetone): 7.73 (*dd*, *J* = 8.3, 7.6, H–C(5)); 7.53–7.47 (*m*, 2 H); 7.38–7.30 (*m*, 4 H); 7.25 (br. *d*, *J* ≈ 8.3, 1 H); 6.94 ('*t*', *J* ≈ 0.7, H–C(3)); 5.44–5.35 ('*AB*', *J* ≈ 6.9, 2 H); 3.81–3.75 (*m*, 2 H); 3.52–3.46 (*m*, 2 H); 3.25 (*s*, 3 H). $^{13}$C-NMR (50 MHz, $CDCl_3$): 166.6 (*s*); 155.7 (*s*); 148.3 (*s*); 136.1 (*d*); 133.4 (2*d*); 130.5 (*s*); 128.9 (2*d*); 128.6 (*d*); 116.2 (*d*); 115.5 (*d*); 114.3 (*s*); 93.6 (*t*); 85.2 (*d*); 71.2 (*t*); 68.1 (*t*); 58.8 (*q*).

A soln. of 585.3 mg (1.69 mmol) of **13** in 10 ml of $CH_2Cl_2$ was oxidized at 0–5° with 1.51 g of *m*-chloroperbenzoic acid (55%) overnight. Usual workup (AcOEt, 30% aq. $Na_2S_2O_5$) and crystallization of the residue from hexane/AcOEt 1:4 gave 621.3 mg (97%) of **4**. M.p. 121.5–122°. UV (*c* = 3.78 · $10^{-5}$ M, MeOH): 298 (3.75), 272 (3.34), 264 (3.26), 217 (4.46). IR ($CHCl_3$): 3075*w* (sh), 3035*w*, 3015*w*, 2995*w* (sh), 2895*w*, 2830*w*, 1792*s*, 1615*m*, 1608*m*, 1588*w*, 1488*s*, 1477*w* (sh), 1451*w*, 1413*w*, 1371*w*, 1353*m* (sh), 1333*s*, 1315*w*, 1289*m*, 1268*m*, 1247*w*, 1210*w* (br.), 1159*s*, 1144*s*, 1109*m*, 1088*m*, 1078*w* (sh), 1056*m*, 998*w* (sh), 986*w*, 940*w*, 900*w* (sh), 892*w*, 836*w*, 800*w*. $^1$H-NMR (200 MHz, ($D_6$)acetone): 7.88–7.75 (*m*, 3 H); 7.83 (*dd*, *J* = 8.3, 7.4, H–C(5)); 7.70–7.60 (*m*, 2 H); 7.52 ('*td*', *J* ≈ 7.6, 0.7, 1 H); 7.40 (br. *d*, *J* ≈ 8.4, 1 H); 6.64 (*d*, *J* = 0.6, H–C(3)); 5.45–5.40 (*AB*, 2 H); 3.80–3.75 (*m*, 2 H); 3.52–3.46 (*m*, 2 H); 3.25 (*s*, $CH_3$). $^{13}$C-NMR (50 MHz, $CDCl_3$): 165.2 (*s*); 156.3 (*s*); 141.2 (*s*); 136.9 (*d*); 134.8 (*d*); 134.7 (*s*); 129.7 (2*d*); 129.2 (2*d*); 117.7 (*d*); 117.0 (*d*); 114.1 (*s*); 94.7 (*t*); 89.7 (*d*); 71.3 (*t*); 68.3 (*t*); 58.9 (*q*). EI-MS (190°): 363 (2), 348 (1), 333 (3), 317 (5), 301 (32), 275 (6), 259 (18), 241 (59), 231 (8), 215 (32), 189 (16), 149 (18), 120 (21), 91 (59), 89 (58), 59 (89), 43 (100). Anal. calc. for $C_{18}H_{18}O_7S$ (378.399): C 57.13, H 4.79, S 8.47; found: C 57.21, H 4.94, S 8.59.

*(2R,4aR,6ξ,7ξ,8R,8aR)-4,4a,6,7,8,8a-Hexahydro-6-nitro-7-[3-oxo-1-(phenylsulfonyl)-1H-isobenzofuran-1-yl]-2-phenyl-2H-pyrano[3,2-d]dioxin-8-yl Acetates* (**8a/8b**) *and (2R,4aR,12R,12aS)-4,4a,12,12a-Tetrahydro-6,11-dioxo-2-phenyl-2H-naphtho[2',3':5,6]pyrano[3,2-d][1,3]dioxin-12-yl Acetate* (**9**). A) A soln. of 117.1 mg (0.36 mmol) of the nitroglycal **7** in 2 ml of THF was added to a mixture of 0.44 mmol (1.20 mol-equiv.) LDA (from 62 µl (i-Pr)$_2$NH and 284 µl of 1.54M BuLi) and of 106.0 mg (0.39 mmol) sulfonyllactone **6** in 5 ml of THF at –70°. The resulting red soln. was stirred for 30 min at –70°, for 15 min at –45°, for 20 min at –20°, and then allowed to warm up to r.t. (15 min). TLC indicated the disappearance of the starting material. The mixture was cooled to –70°, treated with 1 ml of sat. aq. $NH_4Cl$ soln., allowed to warm up to r.t., and worked up as usual (AcOEt, $NaHCO_3$) yielding 222.3 mg (102%) of crude material, which, according to $^{13}$C-NMR, consisted of at the least 4 products. Purification by MPLC (toluene/AcOEt 96:4) gave **9** (9.4 mg, 13%, $R_f$ (toluene/AcOEt 85:15) 0.27) and 2 fractions of a mixture of **8a** ($R_f$ (toluene/AcOEt 85:15) 0.19) and **8b** ($R_f$ (toluene/AcOEt 85:15) 0.16) (39.9 mg, 37%, **8a/8b** 4:1 and 6.8 mg, 6%, **8a/8b** 2:3).

B) A soln. of 224.6 mg (0.70 mmol) of **7** in 4 ml of THF was added to a mixture of 0.85 mmol (1.20 mol-equiv.) of LDA and 200 mg (0.73 mmol) of **6** in 10 ml of THF at –70°. The resulting red soln. was stirred for 45 min. The cooling bath was removed. The soln. was warmed to 40° within 2 h, cooled to –70°, and treated with 4 ml of sat. aq. $NH_4Cl$ soln. Usual workup ($CHCl_3$, $NH_4Cl$, $NaHCO_3$) yielded 328.9 mg (116%) of crude crystals. Recrystallization in hexane/$CHCl_3$ 1:4 afforded 108.3 mg (38%) of **9** as thin, yellow needles. The mother liquor was chromatographed (FC, $CH_2Cl_2$/MeOH 99.5:0.5) to yield an additional amount of 143.6 mg of **9** (total yield 89%). An anal. sample was obtained by recrystallization in hexane/$CHCl_3$ 1:2.

*Data of* **8a** *obtained from a 4:1 mixture* **8a/8b**: $[\alpha]_D^{25} = +8.5$ ($c = 1.38$, $CHCl_3$). IR ($CHCl_3$): 3065*w*, 3030*w*, 3005*w* (sh), 2990*w* (sh), 2940*w*, 2875*w*, 1802*s*, 1794*s* (sh), 1760*m*, 1733*w* (sh), 1600*w*, 1582*w* (sh), 1566*s*, 1560*s* (sh), 1467*w*, 1448*w*, 1370*m*, 1363*w* (sh), 1342*w* (sh), 1328*m*, 1311*w*, 1284*w*, 1270*w* (sh), 1230*m* (br.), 1186*m*, 1177*m* (sh), 1152*s*, 1133*w*, 1118*w*, 1094*m*, 1081*m*, 1050*m*, 1028*w*, 1008*w*, 988*w*, 963*s*, 945*w* (sh), 912*w*. $^1$H-NMR (400 MHz, $CDCl_3$): 7.95–7.90 (*m*, 2 H); 7.80–7.73 (*m*, 4 H); 7.57–7.15 (*m*, 8 H); 6.90 (br. *d*, $J \approx 1.5$, H–C(6); irrad. at 4.63 gives br. *s*); 5.44 (*s*, 1 H); 4.74 (*dd*, $J = 4.1, 1.2$, H–C(7)); 4.63 (br. *dd*, $J \approx 9.1, 4.1$, H–C(8)); 4.48 (br. *dd*, $J = 10.6, 4.7$, H–C(4)); 4.12 ('*t*', $J \approx 10.1$, H'–C(4)); 4.00 (*dd*, $J = 10.7, 9.1$, H–C(8a)); 3.93 ('*td*', $J \approx 10.3, 4.3$, H–C(4a)); 1.89 (*s*, 3 H). $^1$H-NMR (400 MHz, $C_6D_6$): 7.72–7.68 (*m*, 2 H); 7.36–7.29 (*m*, 4 H); 7.05–6.88 (*m*, 4 H); 6.93 (*d*, $J = 1.9$, H–C(6)); 6.69–6.42 (*m*, 4 H); 5.15 (*dd*, $J = 9.1, 4.5$, H–C(8)); 5.04 (*dd*, $J = 4.5, 2.0$, H–C(7)); 5.00 (*s*, 1 H); 4.03 (*dd*, $J = 10.2, 4.6$, H–C(4)); 3.97 (*dd*, $J = 10.5, 9.2$, H–C(8a)); 3.88 ('*td*', $J \approx 10.3, 4.7$, H–C(4a)); 3.77 ('*t*', $J \approx 9.9$, H'–C(4)); 1.47 (*s*, 3 H). $^{13}$C-NMR (50 MHz, $CDCl_3$): 169.9 (*s*); 167.9 (*s*); 141.6 (*s*); 136.3 (*s*); 135.2 (*d*); 134.9 (*d*); 134.4 (*s*); 130.2 (*d*); 130.1 (2*d*); 129.0 (*d*); 128.9 (2*d*); 128.1 (2*d*); 126.5 (*d*); 125.9 (2*d*); 125.2 (*s*); 125.0 (*d*); 102.2 (*d*); 101.4 (*d*); 98.0 (*s*); 74.9 (*d*); 68.5 (*t*); 67.7 (*d*); 67.0 (*d*); 46.7 (*d*); 20.5 (*q*). CI-MS (150°): 549(2), 445(1), 408(4), 407(14), 327(5), 319(3), 285(3), 277(6), 276(8), 275(46), 267(11), 266(10), 265(52), 259(20), 251(21), 235(4), 220(10), 219(51), 218(11), 217(15), 205(3), 199(5), 183(14), 181(6), 175(3), 167(17), 165(12), 149(40), 143(83), 127(8), 125(11), 123(100), 112(9), 106(7), 96(8), 72(17).

*Data of* **8b** *obtained from a 2:3 mixture* of **8a/8b**: $[\alpha]_D^{25} = -16.1$ ($c = 0.73$, $CHCl_3$). IR ($CHCl_3$): 3070*w*, 3035*w*, 3005*w* (sh), 2985*w* (sh), 2940*w*, 2875*w*, 1804*s*, 1760*m*, 1608*w*, 1568*s*, 1562*s* (sh), 1469*w*, 1451*w*, 1378*m* (sh), 1371*m*, 1332*m*, 1313*w*, 1288*w*, 1270*w* (sh), 1230*m* (br.), 1170*m*, 1154*s*, 1133*w*, 1122*w*, 1098*m*, 1083*m*, 1056*m*, 1012*w*, 1003*w*, 966*s*, 945*w* (sh), 917*w*. $^1$H-NMR (400 MHz, $CDCl_3$): 5.52 (*s*, 1 H); 5.28 (*dd*, $J =$ 10.9, 6.6, H–C(8)); 5.14 (*dd*, $J = 6.5, 0.9$, H–C(7)); 4.27 (*dd*, $J = 10.9, 9.1$, H–C(8a)); 2.35 (*s*, 3 H). $^1$H-NMR (400 MHz, $C_6D_6$): 7.75–7.67 (*m*, 2 H); 7.36–7.19 (*m*, 4 H); 7.06–6.87 (*m*, 4 H); 6.89 (br. *s*, H–C(6)); 6.76–6.38 (*m*, 4 H); 5.59 (*dd*, $J = 10.9, 6.5$, H–C(8)); 5.49 (*dd*, $J = 6.5, 0.7$, H–C(7)); 5.26 (*s*, 1 H); 4.59 (*dd*, $J = 10.8, 9.4$, H–C(8a)); 4.13 (*dd*, $J = 10.1, 4.7$, H–C(4)); 4.07 ('*td*', $J \approx 10.3, 3.0$, H–C(4a)); 3.62 ('*t*', $J \approx 9.8$, H'–C(4)); 0.53 (*s*, 3 H). $^{13}$C-NMR (50 MHz, $CDCl_3$): 103.4 (*d*); 78.2 (*d*); 77.3 (*d*); 65.6 (*d*); 61.6 (*t*); 44.0 (*d*).

*Data of* **9**: M.p. 256–258°. $[\alpha]_D^{25} = +86.9$ ($c = 0.58$, $CHCl_3$). UV ($c = 8.29 \cdot 10^{-5}$ M, MeOH): 333 (3.46), 278 (4.04), 249 (4.26), 243 (4.25). CD ($c = 8.29 \cdot 10^{-5}$ M, MeOH): 383 (0), 348 (+1.6), 306 (+0.4), 270 (+5.6), 228 (0). IR ($CHCl_3$): 3070*w* (sh), 3030*w*, 3005*w*, 2940*w*, 2910*w* (sh), 2870*w*, 1774*w* (sh), 1751*m*, 1683*s*, 1660*m*, 1654*m* (sh), 1647*w* (sh), 1613*m*, 1598*w*, 1578*w*, 1569*w* (sh), 1452*w*, 1407*w* (sh), 1386*w* (sh), 1369*m*, 1361*w* (sh), 1329*m*, 1302*m*, 1277*w*, 1230*w* (br.), 1158*w*, 1102*s*, 1057*s*, 1028*m*, 985*w*, 967*w*, 948*w*, 908*w*. $^1$H-NMR (200 MHz, $CDCl_3$): 8.15–8.06 (*m*, 2 H); 7.81–7.69 (*m*, 2 H); 7.52–7.35 (*m*, 5 H); 6.50 (*d*, $J = 8.1$, H–C(12)); 5.64 (*s*, 1 H); 4.67 (*dd*, $J = 10.0, 4.3$, H–C(4)); 4.24–4.02 (*m*, 3 H); 2.15 (*s*, 3 H). $^1$H-NMR (400 MHz, $C_6D_6$): 7.99–7.88 (*m*, 2 H); 7.61–7.58 (*m*, 2 H); 7.15–6.94 (*m*, 5 H); 6.59 (*d*, $J = 8.2$, H–C(12)); 5.19 (*s*, 1 H); 4.10 (*dd*, $J = 10.1, 4.9$, H–C(4)); 3.73 (*dd*, $J = 10.1, 8.2$, H–C(12a)); 3.51 ('*td*', $J \approx 10.2, 4.9$, H–C(4a)); 3.42 (*t*, $J = 10.1$, H'–C(4)); 1.88 (*s*, Ac). $^{13}$C-NMR (100 MHz, $CDCl_3$): 182.0 (*s*); 178.7 (*s*); 169.7 (*s*); 155.7 (*s*); 136.3 (*s*); 134.7 (*d*); 133.6 (*d*); 132.1 (*s*); 130.6 (*s*); 129.3 (*d*); 128.3 (2*d*); 126.5 (2*d*); 126.1 (2*d*); 119.4 (*s*); 101.7 (*d*); 77.0 (*d*); 70.0 (*d*); 67.7 (*t*); 65.0 (*d*); 21.0 (*q*). CI-MS (180°): 409(2), 408(9), 407(28), 392(2), 389(3), 366(6), 365(7, $M^+ - C_3H_5 + 1$), 357(2), 348(4), 347(11, $M^+ - C_2H_3O_2 + 1$), 319(3), 301(4), 283(2), 279(2), 275(7), 271(1), 265(16), 259(23), 251(4), 219(4), 149(11), 143(31), 107(13), 106(100), 104(5), 77(3). Anal. calc. for $C_{23}H_{18}O_7$ (406.390): C 67.98, H 4.46; found: C 67.69, H 4.76.

*(2*R*,4a*R*,12*R*,12a*S*)-4,4a,12,12a-Tetrahydro-12-methoxy-2-phenyl-2*H*-naphtho[2',3':5,6]pyrano-[3,2-*d*][1,3]dioxin-6,11-dione* (**10**). At 0°, 300 µl of 5% NaOMe in MeOH were added to a soln. of 24.3 mg of **9** in 3 ml of MeOH. The mixture was stirred at 0° for 3 h, until TLC indicated near completion of the reaction. Workup as usual ($CHCl_3$, $NaHCO_3$) gave 20.3 mg of crude material. FC (toluene/AcOEt 96:4) yielded 3.2 mg (13%) of **9** and, after crystallization from pentane/AcOEt 2:1, 12.0 mg (55%) of **10** as fine yellow needles. M.p. 215–216°. $[\alpha]_D^{25} = -139.2$ ($c = 0.98$, $CHCl_3$). UV ($c = 2.19 \cdot 10^{-5}$ M, EtOH): 331 (3.32), 276 (3.98), 249 (4.24), 244 (4.23). CD ($c = 2.19 \cdot 10^{-5}$ M, EtOH): 452 (0), 415 (–2.6), 384 (0), 348 (+3.9), 307 (0), 294 (–3.2), 287 (0), 266 (+15.6), 226 (0). IR ($CHCl_3$): 3070*w* (sh), 3035*w* (sh), 3005*w*, 2940*w*, 2910*w* (sh), 2875*w*, 2818*w*, 1689*s* (sh), 1683*s*, 1660*m*, 16574*m* (sh), 1617*s*, 1598*m*, 1581*w*, 1454*w*, 1402*w* (sh), 1386*w*, 1366*w*, 1330*m*, 1302*m*, 1276*w*, 1230*w* (br.), 1192*w*, 1156*w*, 1130*w* (sh), 1120*w* (sh), 1099*s*, 1088*s* (sh), 1056*s*, 1031*m*, 1026*w* (sh), 1007*w*, 972*w*, 956*w* (sh), 946*w*, 914*w*, 882*w*. $^1$H-NMR (400 MHz, $CDCl_3$): 8.15–8.07 (*m*, 2 H); 7.81–7.68 (*m*, 2 H); 7.55–7.36 (*m*, 5 H); 5.71 (*s*, 1 H); 4.68 (*d*, $J = 7.3$, H–C(12), NOE: 3.7%); 4.64 ('*td*', $J \approx 10.3, 5.4$, H–C(4a)); 4.18 (*dd*, $J = 10.2, 7.2$, H–C(12a), NOE: < 1%); 4.11–4.04 (*m*, 2 H); 3.80 (*s*, $CH_3O$–C(12), NOE irradiation). $^{13}$C-NMR (100 MHz, $CDCl_3$): 183.0 (*s*); 179.1 (*s*); 154.8 (*s*); 136.7 (*s*); 134.5 (*d*); 133.4 (*d*); 132.5 (*s*); 130.6 (*s*); 129.2 (*d*); 128.3 (2 *d*); 126.4 (*d*); 126.2 (*d*); 126.0 (2 *d*); 122.3 (*s*); 101.5 (*d*); 80.4 (*d*); 74.3 (*d*);

70.0 (*d*); 67.8 (*t*); 61.1 (*q*). CI-MS: 381 (4), 380 (24), 379 (100, $M^+ + 1$), 348 (11, $M^+ - CH_3O + 1$), 347 (10), 265 (4), 121 (4). Anal. calc. for $C_{22}H_{18}O_6$ (378.380): C 69.84, H 4.80; found: C 69.80, H 4.86.

*(2S,3R,4S)-3,4-Dihydro-9-[(2-methoxyethoxy)methoxy]-2-methyl-3,4-[(1-methylethylidene)dioxy)]-2H-naphtho[2,3-b]pyrane-5,10-dione* (**17**). At –70°, a soln. of 99.2 mg (0.46 mmol) of **5** in 2.5 ml of THF was added to a mixture of 171 mg (0.45 mmol) of **4**, 0.51 mmol (1.1 mol-equiv.) of LDA and 350 mg of molecular sieves of 4 Å in 5 ml of THF under Ar. The cooling bath was removed, and the mixture was exposed to ultrasound at r.t. for 20 h, cooled to –78°, treated with 2 ml of aq. 1M $NH_4Cl$, warmed to r.t., and worked up as usual (AcOEt, $NH_4Cl$, $NaHCO_3$) yielding 217.3 mg of crude material, which was purified by prep. HPLC (*Zorbax SIL 21*, hexane/AcOEt 1:1) to give 118.0 mg (65%) of **17**. $[\alpha]_D^{25} = -116.7$ ($c = 0.22$, acetone). UV ($c = 5.27 \cdot 10^{-5}$ M, MeOH): 366 (3.33), 310 (sh) (3.20), 275 (3.85), 237 (4.08). CD ($c = 5.27 \cdot 10^{-5}$ M, MeOH): 484 (0), 424 (1.6), 396 (0), 352(–3.0), 302 (–0.7), 274 (–3.7), 248 (–1.6), 220 (–3.9). IR ($CHCl_3$): 3035*w*, 2995*w*, 2940*w*, 2895*w*, 2825*w*, 1793*w*, 1748*w*, 1731*w*, 1720*w* (sh), 1681*s*, 1658*w* (sh), 1651*m*, 1633*m*, 1589*s*, 1578*w* (sh), 1562*w*, 1486*w*, 1470*w*, 1450*w*, 1402*w*, 1384*m*, 1376*w*, 1358*w*, 1338*w*, 1314*w*, 1294*w*, 1283*w*, 1240*s* (br.), 1192*s*, 1158*m*, 1136*s*, 1104*s*, 1078*m*, 1042*s*, 1012*s*, 993*s*, 966*w*, 947*s*, 920*w* (sh), 870*w*, 853*w*. $^1$H-NMR (400 MHz, $CDCl_3$): 7.85 (*dd*, $J = 7.6, 1.1$, 1 H); 7.64 (*dd*, $J = 8.4, 7.7$, H–C(7)); 7.49 (*dd*, $J = 8.5, 1.0$, 1 H); 5.43 (br. *s*, 2 H); 5.34 (*d*, $J = 6.5$, H–C(4)); 4.41 (*dd*, $J = 6.5, 1.4$, H–C(3)); 4.21 (*qd*, $J = 6.7, 1.3$, H–C(2)); 3.93–3.90 (*m*, 2 H); 3.58–3.54 (*m*, 2 H); 3.36 (*s*, MeO); 1.67 (*d*, $J = 6.7$, $CH_3$–C(2)); 1.43 (*s*, $CH_3$); 1.34 (*s*, $CH_3$). $^{13}$C-NMR (50 MHz, $CDCl_3$): 183.2 (*s*); 177.8 (*s*); 157.3 (*s*); 155.0 (*s*); 135.1 (*d*); 134.1 (*s*); 121.7 (*d*); 120.7 (*s*); 120.3 (*d*); 118.4 (*s*); 111.0 (*s*); 93.9 (*t*); 74.8 (*d*); 73.0 (*d*); 71.4 (*t*); 68.3 (*t*); 67.1 (*d*); 58.9 (*q*); 27.7 (*q*); 26.0 (*q*); 17.0 (*q*). EI-MS (140°): 404 (1, $M^+$), 363 (2), 346 (1), 328 (2), 316 (14), 301 (87), 290 (2), 259 (35), 241 (100), 230 (10), 215 (63), 203 (9), 189 (14), 127 (10), 121 (18), 89 (100), 59 (100), 43 (100). Anal. calc. for $C_{21}H_{24}O_8$ (404.415): C 62.37, H 5.98; found: C 62.15, H 6.14.

*(2S,3R,4S)-3,4-Dihydro-3,4,9-trihydroxy-2-methyl-2H-naphtho[2,3-b]pyrane-5,10-dione* (*(-)-ent-Cryptosporin*, **18**). A soln. of 478.8 mg (1.18 mmol) of **17** in 9 ml of THF was heated with 7 ml of 1M HCl for 5 h to 60–64°. The mixture was poured onto 10 ml of ice/$H_2O$ and worked up as usual ($CHCl_3$, $NaHCO_3$). Evaporation of the org. phase gave 202.2 mg (62%) of **18** as yellow crystals. M.p. 240–243° (hexane/AcOEt 3:5). M.p. of a 1:1 mixture **18**/**3**[4]): 212–216°. $[\alpha]_D^{25} = -240.9$ ($c = 0.08$, acetone). UV ($c = 6.70 \cdot 10^{-5}$ M, MeOH): 521 (sh) (2.67), 407 (3.61), 285 (3.99), 242 (4.06); after addition of 0.5M of NaOH: 511 (3.67), 383 (3.15), 288 (4.01), 223 (4.39). CD ($c = 6.70\ 10^{-5}$ M, MeOH): 486 (0), 424 (0.6), 406 (0), 364(–1.6), 316 (–0.2), 284 (–4.8), 256 (0), 237 (1.3), 228 (0). IR ($CHCl_3$): 3500*w*, 1648*w*, 1634*m*, 1612*s*, 1582*w*, 1457*w*, 1373*w*, 1317*w*, 1269*s*, 1158*w*, 1103*m*, 1068*m*, 1048*w*, 1017*w*, 990*m*, 966*w*, 923*w*, 858*w*, 838*w*. $^1$H-NMR (400 MHz, ($D_6$)acetone): 11.70 (*s*, 1 H; exchangeable with $D_2O$, HO–C(9)); 7.73 (*dd*, $J = 8.5, 7.5$, H–C(7)); 7.56 (*dd*, $J = 7.6, 1.1$, 1 H); 7.25 (*dd*, $J = 8.5, 1.1$, 1 H); 4.98 (*m*, $w_{1/2} = 9.5$; with $D_2O$: *dd*, $J = 4.4, 0.7$, H–C(4)); 4.87 (*d*, $J = 2.0$; exchangeable with $D_2O$, 1 OH); 4.45 (br. *q*, $J \approx 6.6$; with $D_2O$: *qt*, $J = 6.6, 1.1$, NOE: 2.5%, H–C(2)); 4.00 (*m*, $w_{1/2} = 10.4$; with $D_2O$: *dd*, $J = 4.4, 1.4$, NOE: 0.8%, H–C(3)); 3.96 (br. *s*; exchangeable with $D_2O$, 1 OH); 1.53 (*d*, $J = 6.6$, NOE irradiation, $CH_3$–C(2)). $^{13}$C-NMR (100 MHz, $CDCl_3$): 186.3 (*s*); 183.6 (*s*); 162.0 (*s*); 155.0 (*s*); 137.0 (*d*); 131.8 (*s*); 124.5 (*d*); 119.1 (*d*); 118.6 (*s*); 113.9 (*s*); 75.9 (*d*); 66.7 (*d*); 64.9 (*d*); 16.5 (*q*). CI-MS (190°): 279 (9), 278 (23), 277 (100, $M^+ + 1$), 261 (9), 260 (13), 259 (78), 243 (6), 220 (8), 219 (37), 89 (7), 85 (7). Anal. calc. for $C_{14}H_{12}O_6$ (276.244): C 60.87, H 4.38; found: C 60.61, H 4.59.

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