

45. Synthesis of (all-*E*,2*R*,2'*R*)-Oscillol

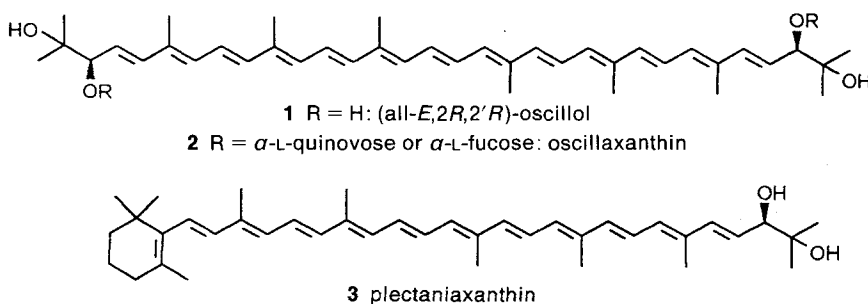
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Optically active (all-*E*,2*R*,2'*R*)-oscillol (= (all-*E*,2*R*,2'*R*)-3,4,3',4'-tetrahydro-1,2,1',2'-tetrahydro- ψ,ψ -carotene-1,2,1',2'-tetrol; **1**) was synthesized according to the $C_{10} + C_{20} + C_{10} = C_{40}$ strategy, applying the Wittig reaction to couple the synthons **4** and **6**. The chiral centre was introduced by a Sharpless dihydroxylation of 3-methylbut-2-enyl 4-nitrobenzoate (**8**).

1. Introduction. – The tetrahydroxycarotenoid oscillol (= 3,4,3',4'-tetrahydro-1,2,1',2'-tetrahydro- ψ,ψ -carotene-1,2,1',2'-tetrol; **1**) has been identified as the aglycon of oscillaxanthin (**2**) which was isolated for the first time by Karrer and Rutschmann from the cyanobacteria *Oscillatoria rubescens* [1]. Later, **2** was isolated also from *Athrospira* sp. [2], *O. princeps* [3], *O. aghardi* [4], and *Spirulina platensis* [5]. α -L-Quinovose [6] [7] and α -L-fucose [5] have been identified as carbohydrate part of **2**. Based on UV/VIS and mass spectra, the constitution of **1** was elucidated by Hertzberg and Liaaen-Jensen [6]. Basic as well as enzymatic hydrolysis of **2** failed, and hydrolysis under acidic conditions led to decomposition of the carotenoid [8]. Based on the comparison of the CD spectra of **2** and plectanixanthin (**3**), the (*R*)-configuration at C(2) and C(2') of oscillol (**1**) was postulated [8].

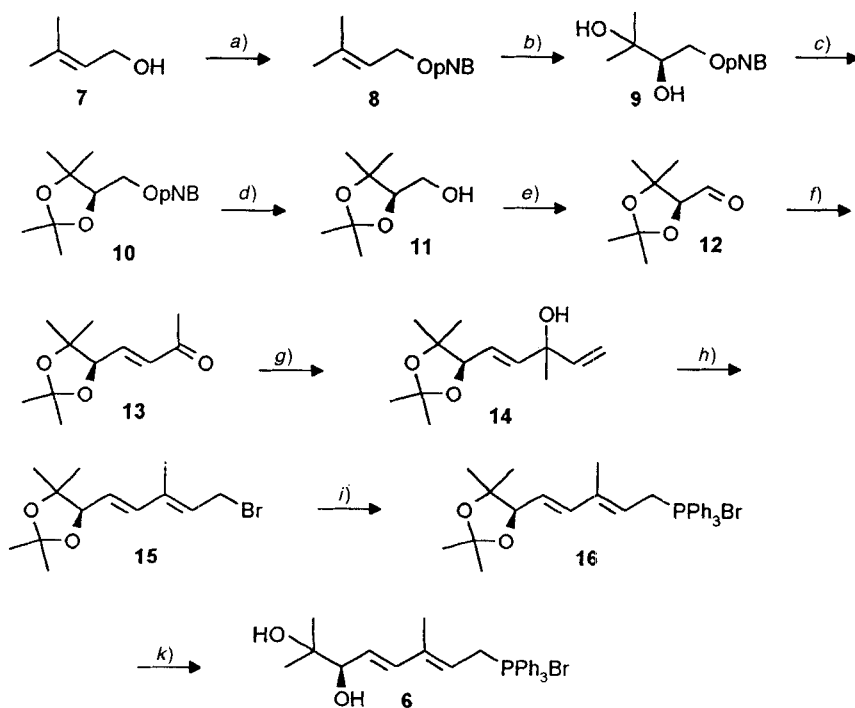


In view of the structure elucidation of oscillol (**1**) and oscillaxanthin (**2**), we report here on the total synthesis of (all-*E*,2*R*,2'*R*)-oscillol (**1**).

¹⁾ Diploma work and part of the Ph. D. thesis of B. Traber.

2. Results and Discussions. – For the total synthesis of **1**, the strategy $C_{10} + C_{20} + C_{10} = C_{40}$, which is often used for the synthesis of acyclic C_{40} -carotenoids, was selected. Having at hand crocetindialdehyde (= 8,8'-diapocarotene-8,8'-dial; **4**) and 15,15'-didehydrocrocetindialdehyde (**5**) as C_{20} -building blocks, the chiral C_{10} -phosphonium salt **6** was the target compound in the present synthesis. As key step for the introduction of the chirality, the *Sharpless* dihydroxylation [9], which is catalyzed by 1,4-bis(dihydroquinidin-9-*O*-yl)phthalazine (DHQD₂-PHAL) and potassium osmate, was selected. The starting material 3-methylbut-2-en-1-ol (**7**) was converted with 4-nitrobenzoyl chloride to ester **8** in 88% yield after recrystallization. The *Sharpless* dihydroxylation [9] of **8** with AD-mix β (see *Exper. Part*) gave the optically active diol **9** with the (2*R*)-configuration in 59% yield. Acetal **10** was obtained by reaction of **9** with dimethoxypropane/TsOH in 77% yield after flash chromatography. Gas chromatography exhibited an enantiomeric excess of 91.4%. By saponification of **10** in *t*-BuOH with aqueous NaOH solution, the primary alcohol **11** was obtained in 90% yield. *Swern* oxidation with oxalyl chloride/DMSO in CH_2Cl_2 gave aldehyde **12** which was converted in a *Wittig* reaction with (acetylmethylidene)triphenylphosphorane to ketone **13** ((*E*)/(*Z*) 68:32) in 76% yield for both steps. The (*E*)/(*Z*) isomers were separated by flash chromatography, and the

Scheme 1

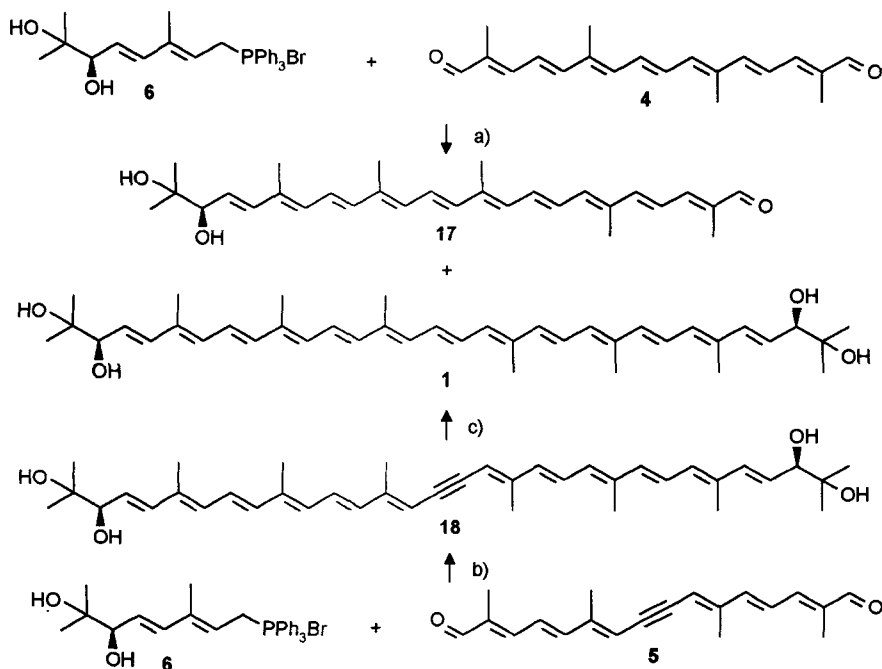


a) 4-NO₂C₆H₄COCl, pyridine. *b*) AD-mix β , MeSO₂NH₂, Na₂SO₃, *t*-BuOH/H₂O. *c*) Dimethoxy-propane, TsOH, acetone. *d*) 2N NaOH, *t*-BuOH. *e*) (COCl)₂, DMSO, CH₂Cl₂, -65°. *f*) AcCHPPh₃, CH₂Cl₂. *g*) CH₂CHMgBr, THF. *h*) PBr₃, petroleum ether. *i*) PPh₃, Et₂O. *k*) 10% AcOH/H₂O.

(*E*)-isomer was reacted in a *Grignard* reaction with vinylmagnesium bromide to give **14** as a mixture of diastereoisomers. The diastereoisomer mixture **14** was reacted with PBr_3 in petroleum ether to give the primary bromide **15** which was immediately converted with PPh_3 in Et_2O to the phosphonium salt **16** in 38% yield for both steps. Hydrolysis of the acetal group in 10% aqueous AcOH solution gave in almost quantitative yield the phosphonium salt **6** (Scheme 1).

The coupling of the phosphonium salt **6** with crocetindialdehyde (**4**) in a two-phase (2N $\text{NaOH}/\text{CH}_2\text{Cl}_2$) *Wittig* reaction resulted in a mixture of (*E/Z*)-isomeric oscillols (41%), the stereoisomeric C_{30} -monoadducts **17** (51%), and unreacted **4** (8%). The by-product Ph_3PO showed in various mixtures of solvents almost the same polarity as oscillol (**1**); its separation was finally achieved by flash chromatography on silica gel with acetone/ Et_3N 200:1. HPLC Analysis of oscillol revealed a mixture of five (*E/Z*)-isomers. The (all-*E*)-isomer **1** was obtained by recrystallization from warm benzene in 3.7% yield relative to **7**. The *Wittig* reaction of **6** with 15,15'-didehydrocrocetindialdehyde (**5**) to 15,15'-didehydrooscillol (**18**) allowed milder reaction conditions (room temperature vs. reflux) with a similar yield (38%) compared to the reaction of **6** with **4**. However, the *Lindlar* hydrogenation did not proceed quantitatively, and due to the similar chromatographical behavior of **1** and **18**, these compounds could not be separated on a preparative scale. As the formation of (*E/Z*)-isomers occurs in both reactions, the second reaction sequence was not further investigated (Scheme 2).

Scheme 2



a) 2N NaOH , CH_2Cl_2 , reflux. b) 2N NaOH , CH_2Cl_2 , r.t. c) H_2 , *Lindlar* catalyst, I_2 , sunlight.

3. Spectroscopical Studies. – All ^1H - and ^{13}C -signals in the NMR spectra of (all-*E*,2*R*,2'*R*)-oscillol (**1**), with the exception of the C(10) and C(12) signal, can be unambiguously assigned by 400-MHz ^1H -NMR, ^{13}C -NMR, DEPT, and ^1H , ^1H -COSY experiments (Table).

Table. ^1H - and ^{13}C -NMR of **1** (400 and 100.6 MHz, resp.; CDCl_3): Chemical Shifts and Coupling Constants

	δ [ppm]	Multiplicity	Coupling constants [Hz]		δ [ppm]
HO–C(1)	ca. 2.08 ^a	<i>s</i>		C(1)	73.07
HO–C(2)	ca. 2.08 ^a	<i>s</i>		C(2)	80.06
H–C(2)	4.00	<i>d</i>	$J(2,3) = 7.61$	C(3)	126.30
H–C(3)	5.71	<i>dd</i>	$J(3,2) = 7.61, J(3,4) = 15.64$	C(4)	138.12
H–C(4)	6.38	<i>d</i>	$J(4,3) = 15.64$	C(5)	134.09
H–C(6)	6.20	<i>d</i>	$J(6,7) = 11.46$	C(6)	138.35
H–C(7)	6.58	<i>dd</i>	$J(7,6) = 11.46, J(7,8) = 15.08$	C(7)	124.27
H–C(8)	6.39	<i>d</i>	$J(8,7) = 15.08$	C(8)	138.73
H–C(10)	6.26	<i>d</i>	$J(10,11) = 11.64$	C(9)	135.97
H–C(11)	6.65	<i>dd</i>	$J(11,10) = 11.64, J(11,12) = 14.66$	C(10) ^b	133.24
H–C(12)	6.40	<i>d</i>	$J(12,11) = 14.66$	C(11)	125.11
H–C(14)	6.28	<i>AA'XX'</i>		C(12) ^b	133.32
H–C(15)	6.65	<i>AA'XX'</i>		C(13)	136.72
CH ₃ (16)	1.18	<i>s</i>		C(14)	132.96
CH ₃ (17)	1.24	<i>s</i>		C(15)	130.38
CH ₃ (18)	1.92	<i>s</i>		C(16)	26.48
CH ₃ (19)	1.97	<i>s</i>		C(17)	23.96
CH ₃ (20)	1.98	<i>s</i>		C(18)	12.98
				C(19)	12.89
				C(20)	12.81

^a) Broad *s*, integration 4 H. ^b) Assignment uncertain.

The UV/VIS spectrum of **1** in MeOH shows a fine structure typical for acyclic carotenoids with maxima at 523, 493, and 468 nm which are in agreement with the data for natural oscillaxanthin (**2**) [10]. The CD spectrum in Et₂O/isopentane/EtOH 5:5:2 (EPA) at -180° shows maxima and minima at 282 (–2.5), 301 (+9.1), 482 (–9.3), 501 (–3.0), 511.5 (–4.6), 531 (+4.5), 552.5 (–0.4), and 572 nm (+7.0). As no CD spectrum of oscillol (**1**) from natural sources is known, no conclusion on the configuration of **1** as aglycone of **2** can be drawn. As shown in the Figure, the CD spectrum of oscillaxanthin hexaacetate [8] shows no similarity to the spectrum of **1**. But the spectra have to be compared with reservations as the spectrum of oscillaxanthin hexaacetate was measured at room temperature [11] and that of **1** at -180° . The comparison with plectanixanthin (**3**) which also possesses a 3,4-didehydro-1,2-dihydro-1,2-dihydroxy- ψ -end group shows that the CD spectrum of **3** and for the corresponding 2'-glycoside are similar [12] [13]. On the other hand, it was demonstrated that the CD spectrum of **3** is strongly temperature-dependent. Additionally, the comparison of the monocyclic chromophore of **3** with the acyclic chromophore of oscillol (**1**) may not be reliable [14] [15]. Considering these limitations on the CD correlations, only a direct comparison of natural and synthetic oscillol (**1**) or oscillaxanthin (**2**) will unambiguously determine the configuration of natural **1**. These investigations are in progress.

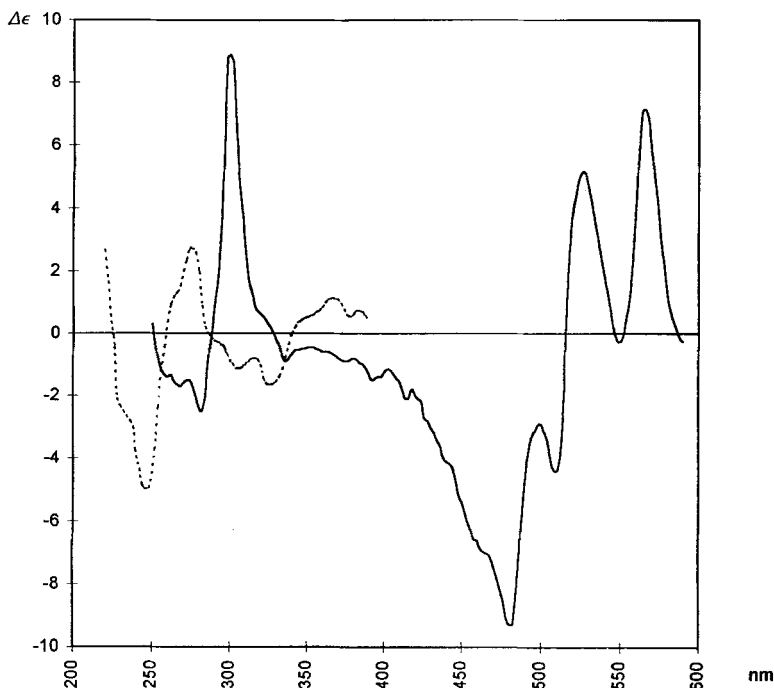


Figure. CD Spectra of oscillaxanthin hexaacetate (---; redrawn from [8]) and of (all-E,2R,2'R)-oscillol (1; —)

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Experimental Part

1. *General.* All experiments were carried out under N₂ or Ar. Solvents were distilled prior to use or purchased in HPLC quality. TLC: Silica gel KG 60, F₂₅₄ (Merck). Flash chromatography (FC): Silica gel 60 (J. T. Baker, 0.040–0.063 mm). Anal. high-pressure liquid chromatography (HPLC): Altex-110A pump, Kontron 720-LC spectrometer, HP-3392A integrator; columns: Macherey-Nagel 720055.6 Nucl. 120-3 C18 and Macherey-Nagel 715.0022 250/VP/10 Nucl. 5 C18. GC: HP-5890; t_R in min. M.p.: Büchi 510, not corrected. [α]_D: Perkin-Elmer-241 polarimeter. UV Spectra: Perkin-Elmer 554; λ_{max} in nm. CD Spectra: modified Jobin-Yvon Dichrograph II, wavelength in nm (Δε). IR Spectra: Perkin-Elmer-782 spectrometer, ν̄ in cm⁻¹. ¹H- and ¹³C-NMR Spectra: Bruker AC-300 (300 and 75.5 MHz, resp.), Bruker AM-400 (400 and 100.6 MHz, resp.); in CDCl₃; chemical shifts in ppm as δ values relative to CDCl₃ (= 7.26 ppm), J in Hz. Mass spectra: Varian MAT CH-7A; m/z (rel. intensity in %); ionization energy 70 eV.

2. *3-Methylbut-2-enyl 4-Nitrobenzoate (8).* To a soln. of 4-nitrobenzoyl chloride (4.3 g, 23 mmol) in dry pyridine (30 ml) cooled to 0° was added dropwise 3-methylbut-2-en-1-ol 7; (2.0 g, 23 mmol). The mixture was stirred for 30 min, the cooling bath removed, and stirring continued for additional 90 min. The mixture was partitioned between Et₂O and 0.5M HCl, washed with sat. aq. NaHCO₃ soln. and brine, dried (MgSO₄), and evaporated. Recrystallization from hot AcOEt/EtOH 1:1 gave 4.75 g (88%) of **8**. Light-yellow needles. M.p. 63°. IR (KBr): 1715s, 1670w, 1610m, 1530s, 1350m, 1280s. ¹H-NMR (300 MHz, CDCl₃): 1.80 (s, Me-C(3')); 1.84 (s, 3 H-C(4')); 4.88 (d, J = 9, 2 H-C(1')); 5.48 (t, J = 9, H-C(2')); 8.27 (m, H-C(2), H-C(3), H-C(5), H-C(6)). ¹³C-NMR (75.5 MHz, CDCl₃): 18.16 (Me-C(3')); 25.83 (C(4')); 62.80 (C(1')); 116.01 (C(2')); 123.50 (C(3), C(5)); 130.74 (C(2), C(6)); 135.96 (C(1)); 140.21 (C(3')); 150.50 (C(4)); 164.78 (C=O). MS: 235 (28, M⁺), 150 (100), 134 (32), 120 (22), 104 (41), 92 (11), 85 (10), 76 (20), 68 (79), 53 (16), 41 (33).

3. (2*R*)-2,3-Dihydroxy-3-methylbutyl 4-Nitrobenzoate (**9**). A soln. of AD-mix β^2 (1.4 g) and methanesulfonamide (95 mg, 1 mmol) in *t*-BuOH/H₂O 1:1 (10 ml) was cooled to 0°. Ester **8** (235 mg, 1 mmol) was added to the orange slurry and stirred for 23 h. Afterwards, Na₂SO₃ (1.5 g, 11.9 mmol) was added, the cooling bath removed, and stirring continued for an additional h. The soln. was extracted with AcOEt and the org. phase washed with 10% aq. KOH soln. and dried (MgSO₄). Purification by FC afforded 160 mg (59%) of **9**. White powder. M.p. 93–94°. [α]_D²⁰ = +5.8 (*c* = 0.04, CHCl₃). IR (KBr): 3520*m*, 3110*w*, 1720*s*, 1610*w*, 1525*s*, 1350*m*, 1275*s*. ¹H-NMR (300 MHz, CDCl₃): 1.30 (*s*, Me–C(3′)); 1.46 (*s*, 3 H–C(4′)); 2.21, 2.82 (2*br. s*, HO–C(2′), HO–C(3′)); 3.86 (*dd*, *J* = 9, 3, H–C(2′)); 4.38 (*dd*, *J* = 12, 9, H–C(1′)); 4.57 (*dd*, *J* = 12, 3, H–C(1′)); 8.27 (*m*, H–C(2), H–C(3), H–C(5), H–C(6)). ¹³C-NMR (75.5 MHz, CDCl₃): 24.50 (Me–C(3′)); 26.52 (C(4′)); 67.03 (C(1′)); 71.71 (C(3′)); 76.20 (C(2′)); 123.55 (C(3), C(5)); 130.75 (C(2), C(6)); 135.15 (C(1)); 150.60 (C(4)); 164.98 (C=O). MS: 270 (1, *M*⁺), 254 (3), 236 (4), 208 (7), 168 (62), 150 (100), 134 (25), 104 (48), 59 (97).

4. (4′*R*)-(2′,2′,5′,5′-Tetramethyl-1′,3′-dioxolan-4′-yl)methyl 4-Nitrobenzoate (**10**). To a soln. of **9** (100 mg, 0.37 mmol) in acetone (20 ml), dimethoxypropane (1.1 ml, 9 mmol) and toluene-4-sulfonic acid (10 mg, 0.05 mmol) were added and stirred for 17 h at r.t. Afterwards Et₃N (1 ml) was added and the soln. evaporated. The residue was partitioned between Et₂O and H₂O and the org. phase washed with brine, dried (Na₂SO₄), and evaporated. Drying under h.v. gave 88 mg (77%) of **10**. Light-yellow powder. GC (150°, 30% DEXYI in OV-170I, 10 m): *t*_R 106.5 ((*R*)-**10**), 109.3 ((*S*)-**10**); enantiomeric excess 91.4%. M.p. 98°. [α]_D²⁰ = +26.4 (*c* = 0.0027, CHCl₃). IR (KBr): 2990*w*, 2960*w*, 1730*s*, 1615*w*, 1530*s*, 1350*m*, 1120*m*. ¹H-NMR (300 MHz, CDCl₃): 1.22 (*s*, Me–C(2′)); 1.39, 1.41 (2*s*, 2 Me–C(5′)); 1.49 (*s*, Me–C(2′)); 4.13 (*dd*, *J* = 7, 5, H–C(4′)); 4.46 (*m*, CH₂–C(4′)); 8.27 (*m*, H–C(2), H–C(3), H–C(5), H–C(6)). ¹³C-NMR (75.5 MHz, CDCl₃): 22.95 (Me–C(2′)); 26.52, 26.97 (2 Me–C(5′)); 28.43 (Me–C(2′)); 64.41 (CH₂–C(4′)); 79.63 (C(5′)); 80.54 (C(4′)); 108.24 (C(2′)); 123.55 (C(3), C(5)); 130.83 (C(2), C(6)); 135.06 (C(1)); 150.65 (C(4)); 164.64 (C=O). MS: 294 (66, [*M* – 15]⁺), 234 (16), 208 (8), 193 (5), 150 (100), 127 (16), 120 (12), 104 (13), 85 (19), 43 (20).

5. (4′*R*)-(2′,2′,5′,5′-Tetramethyl-1′,3′-dioxolan-4′-yl)methanol (**11**). To a soln. of **10** (600 mg, 1.94 mmol) in *t*-BuOH (15 ml), 2*N* NaOH (4 ml) was added and the mixture stirred for 2 h at r.t. The soln. was extracted with Et₂O and the org. phase dried (MgSO₄) and evaporated. Drying under h.v. for 15 min resulted in 280 mg (90%) of **11**. Colorless oil. [α]_D²⁰ = –11.6 (*c* = 0.164, MeOH). IR (NaCl): 3440*m*, 2990*s*, 2885*m*, 1470*w*, 1370*s*, 1220*s*, 1195*s*, 1135*m*. ¹H-NMR (300 MHz, CDCl₃): 1.15 (*s*, Me–C(2′)); 1.33, 1.39 (2*s*, 2 Me–C(5′)); 1.47 (*s*, Me–C(2′)); 2.70 (*br. s*, HO–C(1)); 3.63 (*dd*, *J* = 5, 11, H–C(1)); 3.76 (*dd*, *J* = 10, 11, H–C(4′)); 3.92 (*dd*, *J* = 5, 10, H–C(1)). ¹³C-NMR (75.5 MHz, CDCl₃): 22.98 (Me–C(2′)); 26.67, 26.97 (2 Me–C(5′)); 28.52 (Me–C(2′)); 61.52 (C(1)); 79.56 (C(5′)); 83.78 (C(4′)); 107.66 (C(2′)). MS: 145 (100, [*M* – 15]⁺), 129 (56), 115 (38), 105 (58), 85 (73), 77 (38), 71 (41), 59 (88), 43 (73).

6. (4′*R*,3*E*)-4-(2′,2′,5′,5′-Tetramethyl-1′,3′-dioxolan-4′-yl)but-3-en-2-one (**13**). To a soln. of (COCl)₂ (300 mg, 2 mmol) in CH₂Cl₂ (2.5 ml), DMSO (0.3 ml, 4.5 mmol) in CH₂Cl₂ (1.2 ml) was added and stirred for 15 min at –65°. A soln. of **11** (280 mg, 1.75 mmol) in CH₂Cl₂ (3 ml) was added and the mixture stirred for 1 h. Et₃N (1.3 ml) and, after 10 min stirring, (acetylmethylidene)triphenylphosphorane (930 mg, 2.8 mmol) in CH₂Cl₂ (3 ml) were added, and the soln. was allowed to warm to r.t. The mixture was partitioned between CH₂Cl₂ and half-sat. brine and the org. phase dried (MgSO₄) and evaporated. FC afforded 150 mg (52%) of **13** and 70 mg (24%) of its (*Z*)-isomer, colorless liquids. **13**: [α]_D²⁰ = –140.5 (*c* = 0.04, MeOH). IR (NaCl): 2980*m*, 2935*w*, 2870*w*, 1740*w*, 1675*s*, 1635*w*, 1370*s*. ¹H-NMR (300 MHz, CDCl₃): 1.01 (*s*, Me–C(2′)); 1.27, 1.31 (2*s*, 2 Me–C(5′)); 1.41 (*s*, Me–C(2′)); 2.23 (*s*, 3 H–C(1)); 4.30 (*d*, *J* = 5, H–C(4′)); 6.31 (*d*, *J* = 16, H–C(3)); 6.59 (*dd*, *J* = 5, 16, H–C(4)). ¹³C-NMR (75.5 MHz, CDCl₃): 23.72 (Me–C(2′)); 25.80, 26.80 (2 Me–C(5′)); 27.40 (C(1)); 28.17 (Me–C(2′)); 80.92 (C(5′)); 82.63 (C(4′)); 108.04 (C(2′)); 131.15 (C(3)); 140.10 (C(4)); 197.38 (C(2)). MS: 183 (29, [*M* – 15]⁺), 141 (20), 123 (8), 97 (9), 82 (100), 43 (53).

7. (4′*R*,4*E*)-3-Methyl-5-(2′,2′,5′,5′-tetramethyl-1′,3′-dioxolan-4′-yl)penta-1,4-dien-3-ol (**14**). A soln. of **13** (7.92 g, 40 mmol) in THF (50 ml) was added to 1*M* vinylmagnesium bromide in THF (100 ml) at –10 to –6°. The mixture was stirred for 2 h at 0° and hydrolyzed with cold sat. NH₄Cl soln. (20 ml) so that the temp. did not exceed 8°. The mixture was warmed to r.t. and partitioned between Et₂O and H₂O. The org. phase was dried with MgSO₄ and evaporated. Drying under h.v. for 15 min gave 8.92 g (99%) of **14** (diastereoisomers). Colorless oil. [α]_D²⁰ = –24.8 (*c* = 0.0025, CHCl₃). IR (NaCl): 3440*m*, 3085*w*, 2980*s*, 2935*m*, 2870*w*, 1715*w*, 1645*w*, 1460*w*, 1370*s*,

²⁾ The applied AD-mix β consists of K₃Fe(CN)₆, K₂CO₃, (DHQD)₂-PHAL, and K₂O₈O₂(OH)₄ in a molar ratio of 1500:1500:5:1.

1265m, 1220s, 1195s. ¹H-NMR (300 MHz, CDCl₃): 1.02 (s, Me-C(2'')); 1.18 (s, Me-C(3)); 1.28, 1.33 (2s, 2 Me-C(5'')); 1.38 (s, Me-C(2'')); 4.13 (d, *J* = 8, H-C(4'')); 5.00 (d, *J* = 10, H-C(2)); 5.23 (d, *J* = 10, H-C(4)); 5.60 (dd, *J* = 8, 10, H-C(5)); 5.87 (m, 2 H-C(1)). ¹³C-NMR (75.5 MHz, CDCl₃): 23.49 (Me-C(2'')); 25.66, 26.90 (2 Me-C(5'')); 27.75 (Me-C(3)); 28.34 (Me-C(2'')); 72.80 (C(3)); 80.83 (C(5'')); 84.00 (C(4'')); 107.26 (C(2'')); 112.45 (C(1)); 122.87 (C(5)); 140.02 (C(4)); 143.42 (C(2)). MS: 211 (21, [*M* – 15]⁺), 168 (10), 151 (16), 129 (9), 110 (38), 95 (73), 81 (41), 71 (19), 59 (44), 43 (100).

8. (4'*R*,4*E*)-[3-Methyl-5-(2',2',5',5'-tetramethyl-1',3'-dioxolan-4'-yl)penta-2,4-dien-1-yl]triphenylphosphonium Bromide (**16**). To a soln. of **14** (530 mg, 2.35 mmol) in light petroleum ether at –14°, pyridine (0.1 ml) and a soln. of PBr₃ (0.21 ml, 2.35 mmol) in light petroleum ether (3 ml) were added and stirred for 45 min at –10°. The mixture was hydrolyzed with sat. aq. NaHCO₃ soln. and extracted with Et₂O. The org. phase was washed with brine, dried (MgSO₄), and evaporated. The residue was immediately dissolved in Et₂O (5 ml), and PPh₃ (750 mg, 2.86 mmol) was added. The soln. was stirred for 46 h at r.t. under exclusion of light and the precipitation filtered off and washed with cold Et₂O. Drying under h.v. (12 h) afforded 502 mg (39%) of **16**. Light-yellow powder³⁾. M.p. 89°. [*α*]_D²⁰ = +9.9 (*c* = 0.005, CHCl₃). IR (KBr): 2980m, 1630w, 1585w, 1435s, 1365m, 1260w, 1195m, 1110s. ¹H-NMR (300 MHz, CDCl₃): 0.99 (s, Me-C(2'')); 1.18, 1.27 (2s, 2 Me-C(5'')); 1.48 (s, Me-C(2'), Me-C(3)); 4.12 (d, *J* = 8, H-C(4'')); 4.63 (m, H-C(1)); 4.85 (m, H-C(1)); 5.95 (m, H-C(5), H-C(2)); 6.23 (d, *J* = 13, H-C(4)); 7.66–7.85 (m, 15 arom. H). ¹³C-NMR (75.5 MHz, CDCl₃): 13.40 (C(1)); 23.76 (Me-C(2'')); 24.90 (Me-C(3)); 25.95, 27.13 (2 Me-C(5'')); 28.54 (Me-C(2'')); 81.23 (C(5'')); 84.41 (C(4'')); 107.62 (C(2'')); 117.55 (C(4)); 118.68 (C(2)); 125.28 (3 C(4'')); 130.62 (3 C(3''), 3 C(5'')); 134.03 (3 C(2''), 3 C(5'')); 136.10 (C(5)); 136.17 (3 C(1'')); 142.32 (C(3)). MS: 551 (2, *M*⁺), 339 (15), 313 (10), 277 (19), 262 (100), 183 (57), 152 (14), 135 (16), 108 (23), 95 (30), 81 (32), 67 (22), 55 (23), 44 (28).

9. (6*R*,4*E*)-(6,7-Dihydroxy-3,7-dimethylocta-2,4-dien-1-yl)triphenylphosphonium Bromide (**6**). A soln. of **16** (5.02 g, 1.11 mmol) in 10% aq. AcOH (220 ml) was stirred for 2 h under exclusion of light at 65°. The soln. was evaporated and the residue dissolved in little MeOH and precipitated in Et₂O (500 ml). The precipitation was filtered off, washed with cold Et₂O, and dried under h.v. The filtrate was evaporated and purified by FC (silica gel, AcOEt/acetone/HCOOH 8:1:1). Total yield: 4.54 g (97%) of **6**. White powder. M.p. 132–135°. [*α*]_D²⁰ = +11.4 (*c* = 0.004, MeOH). IR (KBr): 3420s, 2940m, 1715w, 1635w, 1440m, 1380w, 1115m. ¹H-NMR (300 MHz, CDCl₃): 1.00, 1.08 (2s, 3 H-C(8), Me-C(7)); 1.28 (s, Me-C(3)); 3.91 (d, *J* = 8, H-C(6)); 4.40 (m, 2 H-C(1)); 5.29 (m, H-C(2)); 5.61 (m, H-C(5)); 6.14 (d, *J* = 13, H-C(4)); 6.75 (br. s, HO-C(6), HO-C(7)); 7.57–7.82 (m, 15 arom. H). ¹³C-NMR (75.5 MHz, CDCl₃): 12.80 (C(1)); 23.56 (Me-C(7)); 24.64 (Me-C(3)); 26.22 (C(8)); 72.88 (C(7)); 78.66 (C(6)); 117.05 (C(4)); 118.17 (C(2)); 130.09 (3 C(4'')); 130.25 (3 C(3''), 3 C(5'')); 133.54 (3 C(2''), 3 C(6'')); 134.00 (C(1'')); 135.01 (C(5)); 142.88 (C(3)). MS: 413 (7, [*M* – 98]⁺), 369 (9), 277 (49), 262 (100), 249 (12), 199 (18), 183 (63), 170 (15), 157 (27), 152 (29), 131 (17), 115 (14), 108 (34), 82 (20).

10. (2*R*,2'*R*)-3,4,15,3',4',15'-Hexadehydro-1,2,1',2'-tetrahydro-*ψ*,*ψ*-carotene-1,2,1',2'-tetrol (= (2*R*,2'*R*)-15,15'-Didehydroosceillo; **18**). To a soln. of 15,15'-didehydrocrocetindialdehyde (**5**; 10 mg, 34 μmol) in CH₂Cl₂ (2 ml) at 0°, 2*N* NaOH (2 ml) was added. A soln. of **6** (76.4 mg, 149.5 μmol) in CH₂Cl₂ (2 ml) was added dropwise to the mixture. The reaction was protected from light, warmed to r.t., and stirred for 3 h. The soln. was extracted with Et₂O and the org. phase washed with phosphate buffer (pH 7) and evaporated. With FC (silica gel, acetone/Et₃N 200:1), triphenylphosphine oxide was separated from the carotenoids. A second FC (silica gel, hexane/AcOEt 1:1 + 0.5% Et₃N) and drying under h.v. (12 h) resulted in 7.8 mg (38%) of **18**. Red powder. M.p. 196°. UV/VIS (AcOEt): 498, 470, 432, 383, 317. IR (KBr): 3430s, 2960s, 2865m, 1760w, 1675s, 1625m, 1455m, 1385s, 1365s, 1255s, 1220m. ¹H-NMR (300 MHz, CDCl₃): 1.13 (s, 6 H, Me(16,16')); 1.20 (s, 6 H, Me(17,17')); 1.58 (br. s, 4 H, HO-C(1,1'), HO-C(2,2')); 1.87 (s, 6 H, Me(18,18')); 2.05 (s, 12 H, Me (19,19'), Me (20,20')); 3.93 (m, 2 H, H-C(2,2'')); 5.68 (m, 4 H, H-C(3,3'), H-C(14,14'')); 6.20 (m, 4 H, H-C(6,6'), H-C(10,10'')); 6.32 (m, 6 H, H-C(4,4'), H-C(8,8'), H-C(12,12'')); 6.61 (m, 4 H, H-C(7,7'), H-C(11,11'')). MS: 598 (31, *M*⁺), 580 (5), 562 (2), 521 (4), 504 (10), 492 (16), 402 (15), 325 (17), 247 (30), 196 (60), 181 (69), 106 (79), 91 (100), 59 (49).

11. (all-*E*,2*R*,2'*R*)-3,4,3',4'-Tetradehydro-1,2,1',2'-tetrahydro-*ψ*,*ψ*-carotene-1,2,1',2'-tetrol (= (all-*E*,2*R*,2'*R*)-Oscello; **1**). To a soln. of crocetindialdehyde (**4**; 91.6 mg, 0.3 mmol) in CH₂Cl₂ (12 ml), 2*N* NaOH (10 ml) and a soln. of **6** (700 mg, 1.27 mmol) in CH₂Cl₂ (14 ml) were carefully and dropwise added at 0°. The soln. was protected from light, refluxed for 2 h, and extracted with CH₂Cl₂. The org. layer was washed with phosphate buffer (pH 7)

³⁾ A brownish extremely viscous oil was sometimes obtained. It was dissolved in little CH₂Cl₂ and precipitated in vigorously stirred ice-cold 10% Et₂O/hexane.

and evaporated. FC (silica gel, acetone/Et₃N 200:1) separated the carotenoids from triphenylphosphine oxide, and FC (silica gel, hexane/AcOEt 1:1 + 0.5% Et₃N) resulted in 77 mg (41%) of **1** and 96 mg (51%) of C₃₀-monoadduct **17** after drying under h.v. (12 h). **1**: Deep red powder. An anal. sample was recrystallized from warm benzene to give (all-*E*)-isomer **1**. M.p. 225°. UV/VIS (MeOH): 523, 493, 468, 388, 315. CD (EPA, –180°; Δε): 282 (–2.5), 288 (0), 301 (+9.1), 330 (0), 482 (–9.3), 501 (–3.0), 511.5 (–4.6), 519 (0), 531 (+4.9), 550 (0), 552.5 (–0.4), 556.5 (0), 572 (+7.0), 581.5 (0). ¹H-NMR (400 MHz, CDCl₃): Table. ¹³C-NMR (100.6 MHz, CDCl₃): Table. MS: 600 (10, *M*⁺), 582 (1), 506 (4), 494 (42), 417 (6), 400 (8), 388 (13), 157 (52), 145 (67), 105 (76), 91 (100), 59 (68).

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