Synthesis of a Constitutional Isomer of Nerol by Consecutive Ireland–Claisen and Cope Rearrangements

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(2*Z*,6*E*)-3,6-Dimethylocta-2,6-dien-1-ol (**6**) was synthesized by Steglich esterification of (2*E*)-2-methylbut-2-en-1-ol (tiglic alcohol, **7**) with 3-methylbut-2-en-1-oic acid (senecioic acid, **8**), followed by selective Ireland–Claisen rearrangement of the resulting ester **9** at 0°C and subsequent Cope rearrangement of the product at 140°C. A standard LAH reduction in the last step of the synthetic sequence transformed the α,β-unsaturated acid **12** into the target molecule **6**, a constitutional isomer of nerol (**5**) with interesting olfactory properties.

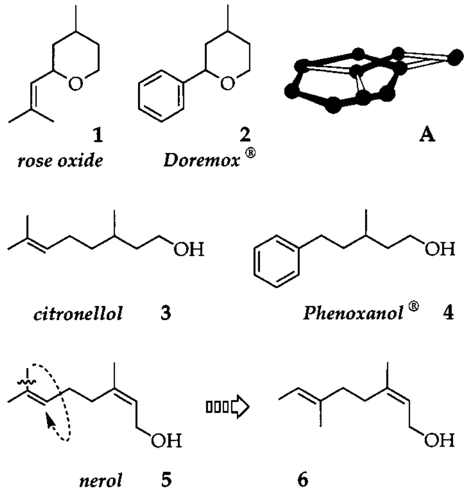
Introduction

The diversity of mono-[1−4] and sesquiterpenoids,[1−3,5] accessible by formal combination of isoprene units, is truly overwhelming, especially when taking into account that with very few exceptions[6] these are joined together only in a *head-to-tail* fashion. With this structural diversity, one finds a variety of molecular shapes and consequently also a variety of physiological properties, for instance odor. However, because of the regular biosynthesis starting from dimethylallyl pyrophosphate, the isobutenyl group is a common structural element of a large number of terpenoids, for instance rose oxide (**1**) and citronellol (**3**). In terms of shape, this isobutenyl group is almost equivalent to a phenyl ring (cf. superposition **A**)[7][8] and this is reflected in the olfactory resemblance of Doremox® (**2**) with rose oxide (**1**), and of Phenoxanol® (**4**) with citronellol (**3**). For further examples see ref.[7][8] We wondered about the importance of this hydrophobic part of terpenoids, and wanted to investigate the influence of the isobutenyl moiety on the odor.

We report the synthesis and olfactory characterization of a constitutional isomer **6** of nerol (**5**). On paper, constitutional isomer **6** can be constructed by shifting the methyl group in the prenyl tail by one carbon atom (Scheme 1). In practice, we made use of a consecutive Ireland−Claisen and Cope rearrangement,[9][10] a synthetic sequence related to the elegant BASF citral process,[11] but on a higher oxidation stage.

Results and Discussion

The required α,β-unsaturated allyl ester, (2′*E*)-2′-methylbut-2-enyl 3-methylbut-2-enoate (**9**), was synthesized by Steglich esterification[12] of 3-methylbut-2-en-1-oic acid (senecioic acid, **8**) with (2*E*)-2-methylbut-2-en-1-ol (tiglic alcohol, **7**) in dichloromethane (Scheme 2). Under protic conditions, (2*E*)-2-methylbut-2-en-1-ol (**7**) rearranged to 3-methylbut-3-en-2-ol, so this mild method offered an efficient alternative to the classical esterification protocol. By flash chromatography on silica gel and subsequent distillation at 61 °C/0.08 mbar **9** was isolated in 90% yield.



Scheme 1. Monoterpenes **1**, **3**, and **5** with an isobutenyl tail, commercial phenyl analogs **2** and **4**, and the idea behind compound **6**

Following a general procedure of Rathke et al.,[13][14] the ester enolate of **9** was formed in the next step by treatment of **9** with lithium cyclohexylisopropylamide (LICA)[13] in THF at −78 °C. Deprotonation takes place predominantly out of the *s-cis* conformation of the senecioic moiety of **9**,[9][15] which leads to the (*Z*)-trimethylsilylketene acetal **10** by reaction with trimethylsilyl chloride at −78 °C.[14] In an Ireland−Claisen reaction[16−18] **10** rearranged at 0 °C within 3d to afford, after mild hydrolysis of the corresponding silyl ester, exclusively the (2*R**,3*S**) isomer of **11** in 98% yield. The *unlike* configuration of **11** was proven by an X-ray crystal structure analysis (Figure 1),[19] and can be rationalized by the chair-type transition state depicted for **10** in Scheme 2. No diastereoisomer of **11** was detectable in the GC trace of the crude reaction product, in contrast to the diastereomeric mixtures (18:82) obtained in the ester-enolate rearrangement of geranyl senecioate.[20] The steric interactions between the trimethylsiloxy group and the β-methyl

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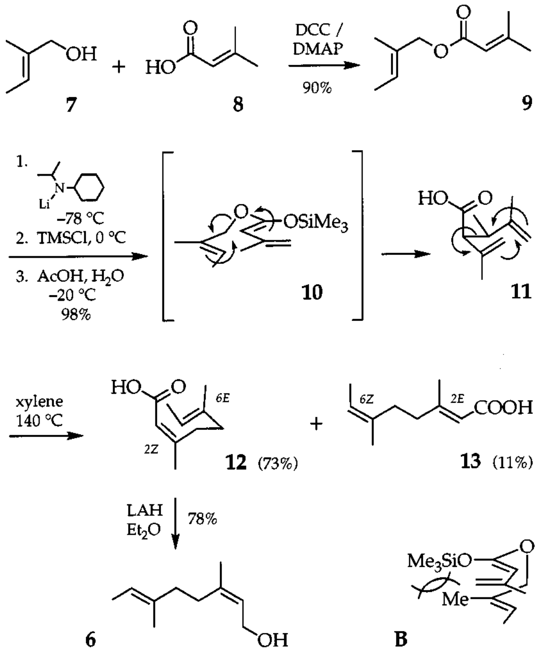
substituent of the 2-methylbut-2-ene moiety in the boat-like transition state **B** (Scheme 2) could explain the high selectivity of this rearrangement, proceeding exclusively via the chair-type transition state depicted for **10**. Similarly, significant diastereoselectivity by a β-substituent in the allylic alcohol moiety had been reported in the Claisen[21] and ortho ester Claisen rearrangements.[22]



Scheme 2. Synthesis of **6** by consecutive Ireland–Claisen and Cope rearrangements of **9**

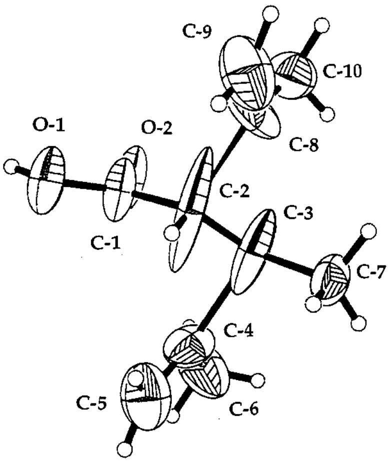


Figure 1. ORTEP view of the X-ray crystal structure of **11**

(2*R**,3*S**)-3,4-Dimethyl-2-(1′-methylethenyl)pent-4-en-1-oic acid (**11**), a 1,5-diene, was then subjected to a Cope rearrangement[18] at 140°C. After 3d, the transformation was completed with one major rearrangement product (GC ratio **12**/**13** 77:23) being formed. This was isolated by flash chromatography to afford in 73% yield crystalline (2*Z*,6*E*)-configured 3,6-dimethylocta-2,6-dien-1-oic acid (**12**). The configuration of the double bonds was established by an NOESY experiment (crosspeaks 2-H ↔ 3-Me, 5-H$_2$ ↔ 7-H, 7-H ↔ 8-H$_3$) and confirmed by X-ray crystallography (Figure 2).[19] The structure of the by-product **13** was assigned by comparison with the ^{13}C-NMR spectra of related reference compounds[23][24] (see Experimental Section); the (2*E*) configuration of the conjugated double bond of **13** is, however, already apparent in the ^{1}H-NMR spectrum. The γ-effect of the carboxy group causes a *downfield* shift of the 3-Me protons (δ = 2.19) compared to those in **12** (δ = 1.92). Consequently, the 4-H$_2$ protons in **12** (δ = 2.72) are *more deshielded* than those in **13** (δ = 2.21).

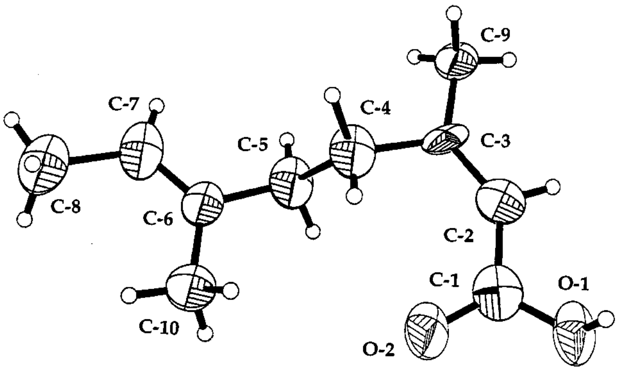


Figure 2. ORTEP view of the X-ray crystal structure of **12**

The four possible transition states for the Cope rearrangement **11** → **12** are shown in Figure 3, the two boat-shaped **E** and **F** of which are sterically very demanding. For the chair-like conformations **C** and **D**, we can estimate the *total destabilization energy* E_D from the experimentally known values for the 1,3-*syn*-diaxial interactions, assuming that $-\Delta G^\circ_{Me/COOH} \approx -\Delta G^\circ_{Me/COOEt}$ = 3.2 kcal·mol^{-1},[25] because $-\Delta G^\circ_{COOH/H} \approx -\Delta G^\circ_{COOEt/H} \approx$ 1.2 kcal·mol^{-1}.[26] With $-\Delta G^\circ_{Me/H}$ = 1.6 kcal·mol^{-1},[26] and $-\Delta G^\circ_{Me/Me}$ = 3.7 kcal·mol^{-1},[27] we obtain:

$$E_D{}^C \approx -\Delta G^\circ_{Me/COOH} - \tfrac{1}{2}\,\Delta G^\circ_{Me/H} - \tfrac{1}{2}\,\Delta G^\circ_{COOH/H} \approx 4.6\ \text{kcal·mol}^{-1} \tag{I}$$

$$E_D{}^D \approx -\Delta G^\circ_{Me/Me} - \Delta G^\circ_{Me/H} = 5.3\ \text{kcal·mol}^{-1} \tag{II}$$

Although this is quite a rough estimation, and even though significant differences were noted for the transition-state *syn*-diaxial interactions of [3,3]-sigmatropic rearrangements compared with those in cyclic systems,[28] the calculated difference of $\Delta E_D \approx -0.7$ kcal·mol^{-1} in the *destabilization energies* of **C** and **D** corresponds quite well with the experimental $\Delta G^\circ_{C/D} = -RT\cdot\ln[(\mathbf{12})/(\mathbf{13})] \approx -1.0$ kcal·mol^{-1}. The constitutional neric acid isomer **12** was then transformed into the target molecule **6** by a standard LAH reduction in ether. After flash chromatography, **6** was

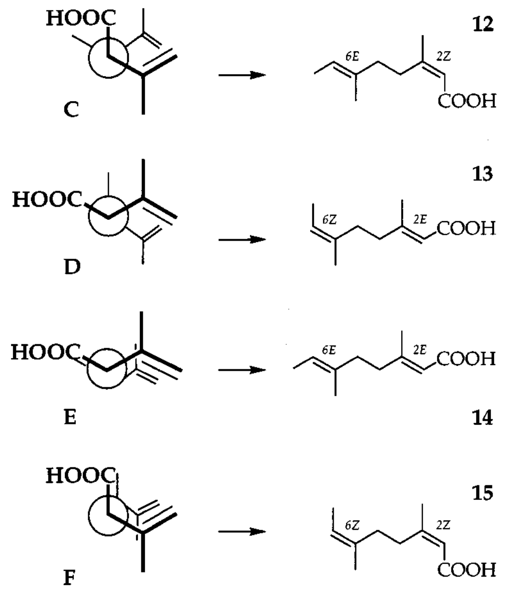


Figure 3. Transition states of the Cope rearrangement **11** → **12**

isolated in 78% yield, and its olfactory properties were evaluated in a comparison to nerol (**5**) and citronellol (**3**).

Olfactory Properties

Nerol (**5**) possesses a typical sweet, transparent rose note with fresh, green geranium-type aspects, and refreshing marine facets as well as some slight nuances recalling lime oil and orange blossoms. Citronellol (**3**) in comparison with **5** misses these fresh, green and marine characteristics, and its warm rose odor is even fatty-waxy and less diffusive than that of **3**, with a fruity pear-type undertone. Phenoxanol (**4**) is relatively close in odor to **3**, however, far less diffusive, and with additional aspects of raspberry, cinnamon bark, diphenyl oxide, and salicylates.

Although the odor of our molecular target, (2*Z*,6*E*)-3,6-dimethylocta-2,6-dien-1-ol (**6**), is still somehow reminiscent of its parent compound nerol (**5**), its main character is lily of the valley (muguet). Like the rosy note of **5**, the odor of **6** is accompanied by marine facets recalling a wet sea shore. Yet it differs from that of **5** by aspects of dimethyl phenyl carbinol and tuberose.

This shift from a rosy to a muguet odor by transposition of only one methyl group **5** → **6** in the hydrophobic prenyl tail is interesting for the structure−odor correlation of floral odorants and would not have been predicted on the basis of the existing olfactophore models in the muguet family.[29][30] Furthermore, muguet odorants with a hydroxy function instead of a reactive aldehyde group are much sought-after.[30]

Experimental Section

IR: Nicolet 510 FT-IR. − NMR: TMS int., Bruker AVANCE DPX-400. − MS: Finnigan MAT 212; HP Chemstation 6890 GC/5973 Mass Sensitive Detector. − FC: Merck Kieselgel 60 (particle size 40−63 µm). − TLC: Merck Kieselgel 60 F_{254} (particle size 5−20 µm, layer thickness 250 µm on glass, 5 cm × 10 cm); visualization reagent: PMA spray solution for TLC, Merck 1.00480.0100. − Melting points: Büchi Melting Point B545 (uncorrected values). − Elemental analyses: F. Hoffmann-La Roche, Basel, PRPI-S. − X-ray: Siemens P4 diffractometer, SHELXS-93/SHELXL-93. − All reactions were performed under nitrogen using reagents and solvents (puriss. or purum) from Fluka without further purification. Tiglic alcohol was prepared by standard LAH reduction of tiglic acid, Fluka 89450. All compounds are racemic.

(2′*E*)-2′-Methylbut-2-enyl 3-Methylbut-2-enoate (9): A mixture of 4-(dimethylamino)pyridine (22.0 g, 180 mmol) and 3-methylbut-2-en-1-oic acid (senecioic acid, **8**) (200 g, 2.00 mol) in dry CH_2Cl_2 (800 mL) was added at 0 °C to a stirred solution of (2*E*)-2-methylbut-2-en-1-ol (tiglic alcohol, **7**) (198 g, 2.30 mol) in anhydrous CH_2Cl_2 (800 mL). *N*,*N*′-Dicyclohexylcarbodiimide (452 g, 2.18 mol) in CH_2Cl_2 (800 mL) was added in one portion, upon which the temp. rose to about 12 °C and pale yellow crystals began to precipitate. Stirring was continued at 0 °C for 30 min and at room temp. for 14 h. The insoluble material was filtered off using a sintered glass funnel, washed twice with 500 mL of CH_2Cl_2 each, and the combined organic solutions were concentrated under reduced pressure. The crude material (438 g) was purified by silica-gel FC (1.5 kg SiO_2, pentane/Et_2O, 9:1, R_f = 0.69), followed by distillation at 61 °C/0.08 mbar to afford 303 g (90%) of **9** as a colorless liquid. − IR (film): $\tilde{\nu}$ = 1144 (s, νC−O), 1719 (s, νOC=O), 1227 (s, ν_{as}=C−CO−O), 1653 (m, νC=C), 1076 (m, ν_{as}O−CH_2−C). − ^1H NMR ($CDCl_3$): δ = 1.63 (d, *J* = 6.0 Hz, 3 H, 4′-H_3), 1.66 (d, *J* = 1.0 Hz, 3 H, 2′-Me), 1.89 (d, *J* = 1.5 Hz, 3 H, *trans* 3-Me), 2.17 (d, *J* = 1.0 Hz, 3 H, *cis* 3-Me), 4.48 (s, 2 H, 1′-H_2), 5.55 (qq, *J* = 6.0 Hz, *J* = 1.0 Hz, 1 H, 3′-H), 5.71 (m_c, 1 H, 2-H). − ^{13}C NMR ($CDCl_3$): δ = 13.09/13.51 (2q, C-4′, 2′-Me), 20.03 (q, *trans* 3-Me), 27.23 (q, *cis* 3-Me), 69.21 (t, C-1′), 115.90 (d, C-3′), 123.50 (d, C-2), 130.98 (s, C-2′), 156.49 (s, C-3), 166.43 (s, C-1). − MS (70 eV); *m/z*: 168 (1) [M^+], 101 (10) [M^+ − C_5H_7], 83 (100) [M^+ − C_5H_7 − H_2O], 69 (11) [$C_5H_9^+$], 55 (10) [$C_4H_7^+$], 41 (10) [$C_3H_5^+$]. − $C_{10}H_{16}O_2$ (168.2): calcd. C 71.39, H 9.59; found C 71.57, H 9.53.

(2*R,3*S**)-3,4-Dimethyl-2-(1′-methylethenyl)pent-4-en-1-oic Acid (11):** Under N_2, *N*-cyclohexylisopropylamine (274 mL, 1.63 mol) was added over 30 min at 0 °C to a stirred solution of *n*BuLi (1.02 L, 1.63 mol, 1.6 M in hexanes). Stirring was continued for an additional 30 min at this temp. prior to removal of the solvent in a vacuum line. The resulting yellow residue was taken up in anhydrous THF (2 L), and (2′*E*)-2′-methylbut-2-enyl 3-methylbut-2-enoate (**9**) (230 g, 1.37 mol) in THF (400 mL) was added dropwise over 45 min at −78 °C. Me_3SiCl (412 mL, 3.26 mol) was then added at −78 °C over 45 min, and stirring was continued for 3d at 0 °C. The reaction was quenched at −20 °C by the dropwise addition (2h) of AcOH (266 mL, 4.66 mol), followed by the dropwise addition of water (1.5 L) within a period of 3 h. The product was extracted with diethyl ether (3 × 2 L), and the combined organic extracts were washed with water (2 L) and a saturated aqueous NaCl solution (2 L), dried (Na_2SO_4) and concentrated in a rotary evaporator to give 234 g of crude material. This was purified by FC (1.5 kg SiO_2, pentane/Et_2O, 4:1, R_f = 0.37) to provide 225 g (98%) of **11** as colorless crystals, m.p. 89.3−90.7 °C (Et_2O/pentane). − IR (KBr): $\tilde{\nu}$ = 1700 (s, νO=CO), 1208 (s, νOC−O), 895/915 (m, ω=CH_2), 1645 (m, νC=C), 3084 (m, νO−H), 941 (m, δO−H o.o.p.). − ^1H NMR ($CDCl_3$): δ = 0.94 (d, *J* = 7.0 Hz, 3 H, 3-Me), 1.73/1.80 (2 s, 6 H, 4-,1′-Me), 2.63 (dq, *J* = 12.0 Hz, *J* = 7.0 Hz, 1 H, 3-H), 3.09 (d, *J* = 12.0 Hz, 1 H, 2-H), 4.76 (d, *J* = 13.0 Hz, 2 H, 5-H_2), 5.00 (d, *J* = 12.0 Hz, 2 H, 2′-H_2), 10.52 (br. s, 1 H, CO_2H). − ^{13}C NMR ($CDCl_3$): δ = 17.23 (q, 3-Me), 19.48/19.90

(2 q, 4-,1′-Me), 40.55 (d, C-3), 58.38 (d, C-2), 110.92/116.32 (2 t, C-5,-2′), 140.71/147.82 (2 s, C-4,-1′), 179.04 (s, C-1). − MS (70 eV); *m*/*z*: 168 (1) [M^+], 153 (5) [$M^+ - CH_3$], 123 (24) [$M^+ - CO_2H$], 100 (32) [$M^+ - C_5H_8$], 82 (20) [$C_6H_{10}^+$], 69 (93) [$C_5H_9^+$], 41 (100) [$C_3H_5^+$]. − Crystal data[19] and structure refinement: Empirical formula $C_{10}H_{16}O_2$, molecular mass 168.23, crystal dimensions 0.35 × 0.35 × 0.15 mm, temperature 193(2) K, wavelength 0.71073 Å, monoclinic crystal system, space group $P2_1/c$. Unit cell dimensions a = 11.274(2) Å, b = 6.2480(12) Å, c = 14.978(3) Å, β = 102.28(3)°, V = 1030.9(4) Å^3, Z = 4, D_x = 1.084 g·cm^{-3}, μ(Mo-K_α) = 0.074 mm^{-1}, F(000) 368, 2θ range 1.85°−21.00°, limiting indices $-1 \le h \le 11$, $0 \le k \le 6$, $-15 \le l \le 14$. Total reflections collected 1324, symmetry-independent reflections 1107, R_{int} = 0.0248, refinement full-matrix least squares on F^2, data 1107, parameters 111, goodness-of-fit on F^2 1.052, final R indices [$I > 2\sigma(I)$] R_1 = 0.0869, wR_2 = 0.2071, R indices (all data) R_1 = 0.1243, wR_2 = 0.2365, extinction coefficient 0.000(6), Δρ (max, min) = 0.480; −0.351 eÅ^{-3}. − $C_{10}H_{16}O_2$ (168.2): calcd. C 71.39, H 9.59; found C 71.28, H 9.47.

(2*Z*,6*E*)-3,6-Dimethylocta-2,6-dien-1-oic Acid (12): Compound **11** (46.0 g, 273 mmol) was heated to 140°C in xylene (750 mL) under N_2 for 3d. Evaporation of the solvent in a rotary evaporator furnished 45.8 g of crude material (GC ratio **12**/**13** 77:23), which was purified by FC (1.3 kg SiO_2, pentane/Et_2O, 9:1, R_f = 0.14) to provide 33.4 g (73%) of **12** as colorless crystals, m.p. 36.0−36.5°C (pentane). − IR (KBr): $\tilde{\nu}$ = 1684 (s, νO=CO, conj.), 1634 (s, νC=C), 1264/1198/1290 (s, νC−O), 1446/1418 (m, δC−O−H i.p.), 928/851/869 (m, δC−O−H, o.o.p.), 2657/2590 (m, νO−H), 1374 (w, δCH_3). − ^{1}H NMR ($CDCl_3$): δ = 1.57 (d, J = 6.5 Hz, 3 H, 8-H_3), 1.64 (s, 3 H, 6-Me), 1.91 (d, J = 1.0 Hz, 3 H, 3-Me), 2.13 (t, J = 8.0 Hz, 2 H, 5-H_2), 2.72 (dd, J = 9.0 and 8.0 Hz, 2 H, 4-H_2), 5.24 (q, J = 6.5 Hz, 1 H, 7-H), 5.68 (d, J = 1.0 Hz, 1 H, 2-H), 12.07 (br. s, 1 H, CO_2H). − ^{13}C NMR ($CDCl_3$): δ = 13.27 (q, C-8), 15.33 (q, 6-Me), 25.57 (q, 3-Me), 32.50 (t, C-4), 38.10 (t, C-5), 115.66 (d, C-2), 118.93 (d, C-7), 135.07 (s, C-6), 163.74 (s, C-3), 172.14 (s, C-1). − MS (70 eV); *m*/*z*: 168 (8) [M^+], 153 (8) [$M^+ - CH_3$], 150 (3) [$M^+ - H_2O$], 123 (47) [$M^+ - CO_2H$], 111 (52) [$M^+ - C_4H_9$], 100 (34) [$M^+ - C_5H_8$], 82 (30) [$C_6H_{10}^+$], 69 (100) [$C_5H_9^+$], 41 (88) [$C_3H_5^+$]. − Crystal data[19] and structure refinement: Empirical formula $C_{10}H_{16}O_2$, molecular mass 168.23, crystal dimensions 0.01 × 0.2 × 0.1 mm, temperature 194(2) K, wavelength 1.54178 Å, monoclinic crystal system, space group $P2_1/n$. Unit cell dimensions a = 6.057(2) Å, b = 6.456(10) Å, c = 25.619(18) Å, β = 91.97(3)°, V = 1001.2(17) Å^3, Z = 4, D_x = 1.116 g/cm^3, μ(Cu-K_α) = 0.606 mm^{-1}, F(000) 368, 2θ range 3.45−54.55°, limiting indices $0 \le h \le 6$, $-6 \le k \le 1$, $-27 \le l \le 27$. Total reflections collected 1667, symmetry-independent reflections 1236, R_{int} = 0.2502, refinement full-matrix least squares on F^2, data 1236, parameters 111, goodness-of-fit on F^2 1.844, final R indices [$I > 2\sigma(I)$] R_1 = 0.1687, wR_2 = 0.3863, R indices (all data) R_1 = 0.2572, wR_2 = 0.4298, extinction coefficient 0.000(3), Δρ (max, min) = 0.436; −0.377 eÅ^{-3}. − $C_{10}H_{16}O_2$ (168.2): calcd. C 71.39, H 9.59; found C 71.42, H 9.40.

(2*E*,6*Z*)-3,6-Dimethylocta-2,6-dien-1-oic Acid (13): Besides **12**, silica gel FC (pentane/Et_2O, 9:1, R_f = 0.08) provided also 5.20 g (11%) of **13** as a yellowish liquid. − IR (film): $\tilde{\nu}$ = 1692 (s, νO=CO, conj.), 1640 (s, νC=C), 1251/1293/1175 (s, νC−O), 2929 (s, νO−H), 1435 (m, δC−O−H, i.p.), 1376 (m, δCH_3), 870/936 (m, δC−O−H, o.o.p.). − ^{1}H NMR ($CDCl_3$): δ = 1.56 (d, J = 5.5 Hz, 3 H, 8-H_3), 1.69 (s, 3 H, 6-Me), 2.19 (d, J = 1.0 Hz, 3 H, 3-Me), 2.21 (m_c, 4 H, 4-,5-H_2), 5.25 (q, J = 5.5 Hz, 1 H, 7-H), 5.71 (d, J = 1.0 Hz, 1 H, 2-H), 11.51 (br. s, 1 H, CO_2H). − ^{13}C NMR ($CDCl_3$): δ = 13.15 (q, C-8), 19.13 (q, 3-Me), 23.17 (q, 6-Me), 29.54 (t, C-5), 39.25 (t, C-4), 115.23 (d, C-2), 120.07 (d, C-7), 134.39 (s, C-6), 163.05 (s, C-3), 172.53 (s, C-1). − The geometry of the double bonds was assigned by comparison of the ^{13}C-NMR shifts of the 3-Me, C-5 and 6-Me signals with those of related reference compounds.[23][24] − MS (70 eV); *m*/*z*: 168 (3) [M^+], 153 (5) [$M^+ - CH_3$], 139 (3) [$M^+ - CHO$], 123 (28) [$M^+ - CO_2H$], 111 (18) [$M^+ - C_4H_9$], 100 (34) [$M^+ - C_5H_8$], 82 (20) [$C_6H_{10}^+$], 69 (85) [$C_5H_9^+$], 41 (100) [$C_3H_5^+$].

(2*Z*,6*E*)-3,6-Dimethylocta-2,6-dien-1-ol (6): At room temp. under N_2, a solution of **12** (15.0 g, 89.2 mmol) in anhydrous Et_2O (180 mL) was added dropwise, with stirring, over 20 min to a suspension of $LiAlH_4$ (4.00 g, 105 mmol) in anhydrous Et_2O (90 mL). After heating at reflux for 5 h, and stirring at room temp. for an additional 12 h, the reaction was quenched by the dropwise addition (1 h) of water (7.2 mL, 400 mmol). $MgSO_4$ (12.0 g, 99.7 mmol) was then added in one portion, and after stirring for 5 min the mixture was filtered with suction through a pad of Celite. Evaporation of the solvent in a rotary evaporator provided 11.3 g of crude material that was purified by FC (300 g SiO_2, pentane/Et_2O, 4:1, R_f = 0.22) to provide **6** (10.7 g, 78%) as a colorless odoriferous liquid. − IR (film): $\tilde{\nu}$ = 1003 cm^{-1} (s, νC−O), 1447/1379 cm^{-1} (s, νCH_2/νCH_3), 3331 cm^{-1} (s, νO−H), 1669 cm^{-1} (m, νC=C). − ^{1}H NMR ($CDCl_3$): δ = 1.17 (s, 1 H, OH), 1.57 (d, J = 6.5 Hz, 3 H, 8-H_3), 1.62 (s, 3 H, 6-Me), 1.74 (s, 3 H, 3-Me), 2.04 (t, J = 8.0 Hz, 2 H, 5-H_2), 2.15 (dd, J = 9.5 Hz, J = 8.0 Hz, 2 H, 4-H_2), 4.08 (d, J = 7.0 Hz, 2 H, 1-H_2), 5.21 (q, J = 6.5 Hz, 1 H, 7-H), 5.41 (t, J = 7.0 Hz, 1 H, 2-H). − ^{13}C NMR ($CDCl_3$): δ = 13.22 (q, C-8), 15.58 (q, 6-Me), 23.39 (q, 3-Me), 30.68 (t, C-4), 38.19 (t, C-5), 58.78 (t, C-1), 118.82 (d, C-7), 124.24 (d, C-2), 135.33 (s, C-6), 139.76 (s, C-3). − MS (70 eV); *m*/*z*: 154 (1) [M^+], 139 (4) [$M^+ - CH_3$], 136 (6) [$M^+ - H_2O$], 123 (100) [$M^+ - CH_2OH$], 107 (62) [$C_8H_{11}^+$], 93 (34) [$C_7H_9^+$], 84 (73) [$C_6H_{12}^+$], 69 (77) [$C_5H_9^+$], 41 (88) [$C_3H_5^+$]. − $C_{10}H_{18}O$ (154.3): calcd. C 77.87, H 11.76; found C 77.91, H 11.74. − Odor: lily of the valley (muguet), rosy, marine, wet sea shore, aspects of dimethyl phenyl carbinol and tuberose.

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