contains two unidentified impurities by GC. Recrystallized from MeOH, **5** sublimes at 208–210 °C: $[\alpha]_D$ −27.9° (*c* 0.03, $CHCl_3$); IR (KBr) 3284–3263, 3056, 1102, 1080, 1049, 1032, 972, 799 cm^{-1}; UV λ_{max} (EtOH) 250 nm (17 717). The retention times for **4** and **5** on an SP-2401 GC column are 8.4 and 7.4 min when cholesterol emerges at 7.7 min.
(24) Compound **5** is also reduced to compound **6** by this procedure.
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Synthesis of (±)-Helenynolic Acid[1]

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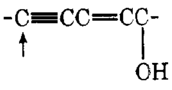
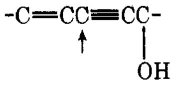
Helenynolic acid (**1**) occurs naturally in the seeds of *Helichrysum bracteatum* family of compositae.[2] The structure and stereochemistry of this unusual enynolic fatty acid were determined by degradation and spectroscopy.[3,4] An elegant conversion of natural crepenyic acid to **1** has been reported but is impractical for providing **1** in useful quantity.[5]

As part of our studies of naturally occurring acetylenes of biogenetic importance, we have developed an efficient synthesis of ±−**1** as shown in Scheme I. This sequence provides **1** in good yield and displays two useful synthetic steps. The Chodkiewicz–Cadiot coupling reaction between **3** and 1-bromoheptyne in the presence of cuprous chloride occurs readily in the presence of the unprotected hydroxy function.[6] Reduction of **4** with lithium aluminum hydride occurs both stereoselectively and regioselectively to give ±−**1**. Stereoselectivity is common for propargyl alcohol reduction but regioselectivity in conjugated systems is not as well documented.[7] Accordingly, conjugated enynolic systems A,[9] which is converted to an allenic system, and B[9] are reduced with specificity for the acetylenic bond. The diynolic system C, however, shows reduction selectively for the acetylenic bond nearest the hydroxy function. These findings hold importance for the design of selective synthesis for other enynolic systems.[10]



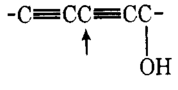
$$\underset{\uparrow}{\text{-C}}\equiv \text{CC}=\underset{\text{OH}}{\underset{|}{\text{C}}}\text{C-}$$

A



$$\text{-C}=\text{C}\underset{\uparrow}{\text{C}}\equiv\underset{\text{OH}}{\underset{|}{\text{C}}}\text{C-}$$

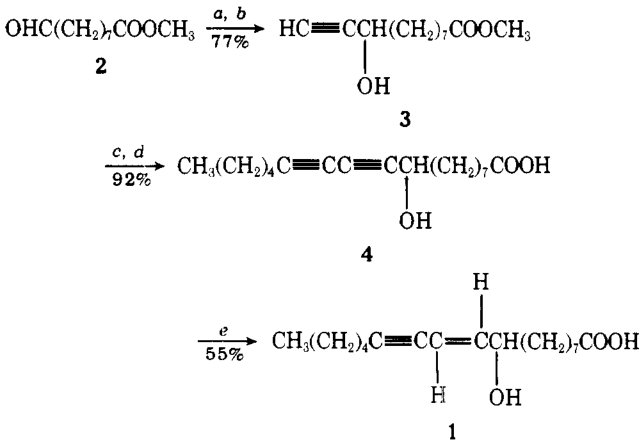
B



$$\text{-C}\equiv\text{C}\underset{\uparrow}{\text{C}}\equiv\underset{\text{OH}}{\underset{|}{\text{C}}}\text{C-}$$

C

Scheme I



$$OHC(CH_2)_7COOCH_3 \ (\mathbf{2}) \xrightarrow[77\%]{a,\,b} HC\equiv C\underset{OH}{\underset{|}{C}}H(CH_2)_7COOCH_3 \ (\mathbf{3}) \xrightarrow[92\%]{c,\,d} CH_3(CH_2)_4C\equiv CC\equiv C\underset{OH}{\underset{|}{C}}H(CH_2)_7COOH \ (\mathbf{4}) \xrightarrow[55\%]{e} CH_3(CH_2)_4C\equiv C\underset{H}{\underset{|}{C}}=\overset{H}{\overset{|}{C}}\underset{OH}{\underset{|}{C}}H(CH_2)_7COOH \ (\mathbf{1})$$

[a] $HC{\equiv}CH$, KOH. [b] CH_2N_2. [c] $CH_3(CH_2)_7C{\equiv}CBr$, CuCl. [d] KOH. [e] $LiAlH_4$, THF.

Experimental Section

Methyl 9-oxononanoate (2) was obtained by ozonolysis of methyl oleate as described by Pryde.[11] Reaction workup to produce the aldehyde was best effected with the use of acetic acid, water, and amberlite MB-3 resin.

Methyl 9-Hydroxyundec-10-ynoate (3). A modification of the procedure described by Stansbury and Proops[12] was used in which a mixture of 30 g of fused potassium hydroxide and 140 mL of anhydrous 1,2-dimethoxyethane was ground in a Waring blender for 0.5 h. A container of dry ice–2-propanol suspended above the blender blades cooled the mixture to 20–30 °C while the blender was operating. The resulting suspension of potassium hydroxide was transferred to a 500-mL, three-necked, round-bottomed flask fitted with a 100-mL pressure equalizing addition funnel, a gas diffusion tube, and a mechanical stirrer. The mixture was cooled to −5 °C, 1.0 mL of absolute ethanol was added, and the suspension was saturated with dry acetylene. A solution of methyl 9-oxononanate (12.9 g, 0.7 mol) in 13 mL of 1,2-dimethoxyethane and 1.0 mL of absolute ethanol was added dropwise over 0.5 h while the slow addition of acetylene was continued. The mixture was poured into cold ice water, acidified, and extracted with benzene–ether (1:1). The dried extracts were concentrated on a rotary evaporator. The crude acid product was esterified with diazomethane and distilled at 100–123 °C (0.15 mm) to give 11.5 g (77%) of pure ester: IR (CCl_4) 3600–3500 cm^{-1} (OH), 3310 ($C{\equiv}CH$), 2125 ($C{\equiv}C$), 1735 ($C{=}O$), and 1165 (C—O); NMR (CCl_4) δ 4.25 (m, 1 H, CH of alcohol), 3.6 (s, 3 H, CH_3), 2.7–3.1 (broad, 1 H, -OH), 2.3 (d, 1 H, $C{\equiv}CH$), 2.2 (m, 2 H, CH_2 $C{=}O$), 1.2–1.8 (broad, 12 H, aliphatic). Anal. Calcd for $C_{12}H_{20}O_3$: C, 67.92: H, 9.43. Found: C, 67.67; H, 9.33.

Attempts to prepare **3** by reaction of **2** with sodium acetylide were unsuccessful.

1-Bromo-1-heptyne was obtained in 67% yield from bromination of 1-heptyne in KOH–dimethoxyethane as described by Brandsma:[13] IR (CCl_4) 2250 cm^{-1} ($C{\equiv}CBr$); NMR (CCl_4) δ 2.2 (m, 2 H, $-CH_2C{\equiv}C$), 1.4 (m, 6 H, CH_2), 0.95 (m, 3 H, CH_3).

9-Hydroxyoctadeca-10,12-diynoic Acid (4). A mixture of **3** (1.06 g, 4 mmol), methanol (12 mL), cuprous chloride powder (10 mg), 33% isopropylamine (1.4 mL), and hydroxylamine hydrochloride (10 mg) was treated with 1-bromo-1-heptyne (0.88 g, 5 mmol) with stirring during 0.5 h. Small amounts of hydroxylamine hydrochloride were added to discharge the blue color which developed. A solution of potassium cyanide (25 mg) in 5 mL of water was added. Extraction with ether gave after drying and concentration a nearly quantitative yield of crude methyl 9-hydroxyoctadeca-10,12-diynoate which was purified by conversion to the acid with methanolic potassium hydroxide: 1.88 g (92%); IR (CCl_4) 3570 (OH), 3500–2800 (COOH), 2220 ($C{\equiv}CC{\equiv}C$), 1680 cm^{-1} ($C{=}O$); NMR (CCl_4) δ 87.4 (b, 1 H, COOH), 4.35 (m, 1 H, CH of alcohol), 2.3 (m, 4 H, CH_2), 1.8–1.2 (m, 18 H, aliphatic). Anal. Calcd for $C_{18}H_{28}O_3$: C, 73.97; H, 9.59. Found: C, 74.04; H, 9.30.

9-Hydroxyoctadec-*trans*-10-en-12-ynoic Acid (Helenynolic Acid, 1). A mixture of **4** (0.7 g), tetrahydrofuran (25 mL), and lithium aluminum hydride (0.3 g) was heated at reflux for 24 h. Moist ether was added to destroy the excess $LiAlH_4$. Water was added and the mixture was extracted with ether. The dried ($MgSO_4$) ether extract was concentrated to give a crude oil which was chromatographed on silica gel G (300 μm) with 2,2,4-trimethylpentane–2-propanol–ether–formic acid (200:40:1:1). The product was collected at R_f 0.11 (0.38 g; 55%): IR (neat) 3600–3200 (OH) 3200–2500 (COOH), 2250 ($C{\equiv}C$), 1710 ($C{=}O$), 1705 cm^{-1} ($C{=}C$); UV (CH_3OH) 228, 235 nm; NMR (CCl_4) δ 6.3–6.9 (two doublets, 1 H, $C{=}CH$), 5.8–5.5 (m, 1 H, $C{\equiv}CC{=}C$), 4.4 (m, 1 H, CH), 2.3 (m, 5 H, $CH_2C{=}O$, $CH_2C{\equiv}C$, COH), 1.35 (m, 18 H, CH_2), and 0.9 (m, 3 H, CH_3).

Acid **1** was converted quantitatively to methyl helenynoate by reaction with diazomethane. IR, NMR, and UV analysis were identical with spectra reported in the literature:[3] IR (neat) 3600–3200 (OH), 2250 ($C{\equiv}C$), 1735 ($C{=}O$), 1625 ($C{=}C$), 953, 718 cm^{-1}; NMR (CCl_4) δ 6.3–5.9 (two doublets, 1 H, $C{=}CHCO$), 5.8–5.5 (m, 1 H, $C{\equiv}CCH{=}C$), 4.4 (m, 1 H, CHO), 3.7 (s, 3 H, CH_3), 2.4–2.0 (m, 5 H, $CH_2C{=}O$, $CH_2C{\equiv}C$, OH), 1.4 (m, 18 H, $-CH_2-$), and 0.95 (m, 3 H, CH_3); UV (CH_3OH) 228, 235 nm. Anal. Calcd for $C_{19}H_{31}O_3$: C, 74.26; H, 10.10. Found: C, 74.11; H, 9.96.

Registry No.—**1**, 68538-95-4; **2**, 1931-63-1; **3**, 68475-05-8; **3** acid, 68475-07-0; **4**, 68475-06-9; methyl helenynoate, 68538-96-5; acetylene, 74-86-2; 1-bromo-1-heptyne, 19821-84-2.

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Conformational Effects and Regiospecificity in Conjugated Dienone Photoisomerization

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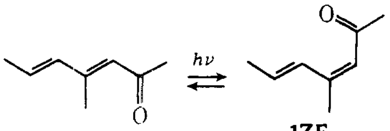
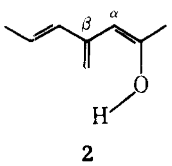
Regiospecific photoisomerization of rhodopsin at its 11-cis double bond is the key photochemical event in vision,[1] and regiospecific triplet-sensitized isomerization of trienones and related compounds has been reported.[2] Regiospecific dienone photoisomerization is rare, however. Quantum yield studies reveal that singlet or triplet excitation of any of the known 3,5-heptadienone isomers, *E,E*, *E,Z*, or *Z,E*, gives *directly* the other two.[3-6] Of a series of aliphatic and δ-phenyl dienones, only 4-methyl-3,5-heptadienone (**1**) undergoes regiospecific photoisomerization.[7]



1EE **1ZE**

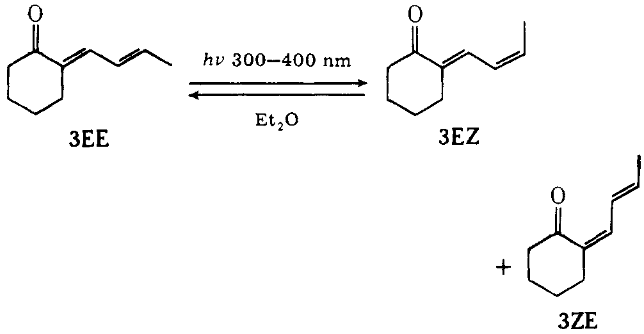
Several causes for the unique behavior of **1** can be proposed. Effecient enolization of excited dienone could lead to exclusive α,β isomerization via the enol (**2**). Alternatively the cause may be conformational. For example, 1,3-diene triplets undergo rapid rotation about their 1,2 and 3,4 bonds, but are incapable of rotation about their central (2,3) bonds.[8] This leads to separate s-cis and s-trans excited dienes which exhibit distinct chemical properties.[9,10] Excited dienones may behave similarly.[4] Infrared and UV data reveal that all the α,β-*E* dienones which we photoisomerized[3] existed as mixtures of s-cis and s-trans enone conformers with the exception of **2**.[11] These 4-methyl-substituted dienones have exclusively s-cis enone units owing to steric destabilization of their s-trans conformers.[12] The unique behavior of their excited states of **1** may derive from the absence of s-trans enone units.



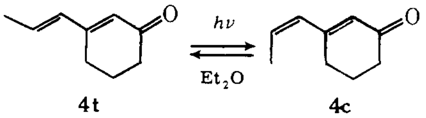
2

Reinvestigation of the photoisomerization of 4-methyl-3,5-heptadienone confirmed our initial report of this unusual regiospecific photoisomerization. An attempt to prepare the "missing" *E,Z* isomer so that its photochemical behavior could be studied was unsuccessful.[13] Tests for photoenolization were carried out by irradiation of **1EE** in deuterated solvents. Photoenolization would lead to deuterium incorporation into the dienone at the 4-methyl group under these conditions.[14] Irradiation of **1EE** in methanol-O-d_1 and in diethyl ether saturated with deuterium oxide proceeded normally and was continued for 1 h after the photostationary state had been reached. Control reactions in methanol and water-saturated ethyl ether were also carried out. Analysis of the photoproducts by GLC-mass spectrometry showed the same M + 1/M signal intensity ratio for samples of **1EE** and of **1ZE** from both deuterated and undeuterated media. Thus, no deuterium incorporation has taken place, and we can conclude that photoenolization does not occur.

The possible effect of the s-cis enone conformation on photoisomerization was tested by studying 2-butenylidenecyclohexanone (**3**).[15,16] This compound lacks the β substituent of **2**, but the ring locks its enone unit in the s-cis conformation. Irradiation of **3EE** gave a photostationary mixture of three isomers. The same photostationary mixture was produced starting from the photoisomers. Structures were assigned on the basis of IR, NMR, and UV spectra which are well known for sets of isomeric dienones.[11,17] Thus, locking the enone unit into the s-cis conformation did not lead to regiospecific photoisomerization.



Conformational influence on quantum yields for photoisomerization was studied using 3-(1-propenyl)-2-cyclohexenone (**4**),[3,18] which possesses a locked s-trans enone unit. Enone unit isomerism, far more than diene unit isomerism, seems the possible cause of such an effect.[4] Quantum yields for photoisomerization of **4** in ether, determined at three wavelengths, are presented in Table I. The 254- and 313-nm values for trans to cis photoisomerization are different at a high level of confidence. Thus, conformational isomerism of the enone unit cannot be the only factor which contributes to the observed wavelength dependence.[4]



4t **4c**

Beyond photoenolization and enone conformational effects, now eliminated, several other possible causes for regiospecific photoisomerization of **1** should be assessed. Depletion of the photostationary concentration of the missing *E,Z* isomer owing to preferential excitation is unlikely. Nonplanarity caused by relief of a 1,3-dimethyl interaction should lead to reduced, not enhanced, UV absorption by this isomer.[11] The steric destabilization of the *E,Z* isomer would be expected to bias decay ratios of nonplanar excited dienones against *E,Z* formation. However, behavior of isomeric 1,3-pentadiene triplets, which possess "allyl methylene" geometry, suggests

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