25,26,27-Trimethyl-6β-methoxy-3α,5-cyclocholestan-24-one (7). A 2.4 M solution of *n*-butyllithium in hexane (1.75 mL, 4.2 mmol) was added at 0 °C under nitrogen gas to diisopropylamine (404 mg, 4.0 mmol) in anhydrous THF (10 mL). The solution was stirred at 0 °C for 15 min and cooled to −78 °C. A solution of 3-ethyl-3-methyl-2-pentanone (11)[14] (487 mg, 3.8 mmol) in THF (3 mL) was added dropwise during 5 min, and the solution kept at −78 °C for 90 min. The iodide 6[13] (456 mg, 1.0 mmol) in THF (3 mL) was added and the cooling bath was removed. The reaction mixture was heated to reflux (1 h) and left at room temperature overnight. Workup with water and ether, washing of the organic phase with HCl and sodium bicarbonate solution, drying over magnesium sulfate, and evaporation yielded a crude product, which was subjected to column chromatography on silica gel (hexane–ether, 10:1) to give the desired product 7 (142 mg, 31%) and recovered starting material 6 (288 mg, 50%): ^{1}H NMR (360 MHz) δ 0.710 (3, s, C-18 Me), 0.757 (6, t, *J* = 7.6, C-29/C-30 Me), 0.905 (3, d, *J* = 6.6, C-21 Me), 1.018 (3, s, C-19 Me), 1.042 (3, s, C-28 Me), 3.321 (3, s, C-6 OMe); mass spectrum, *m/z* 456 (M[+], $C_{31}H_{52}O_2$).

25,26,27-Trimethylergosta-5,24(28)-dien-3β-ol (25-Methylxestosterol, 1). Methyltriphenylphosphonium bromide (639 mg, 1.79 mmol) was suspended in anhydrous THF (5 mL) under an atmosphere of nitrogen. A solution of 2.4 M *n*-butyllithium in hexane (0.75 mL, 1.80 mmol) was added dropwise. The suspended material dissolved and gave a yellow solution, which was heated to 50 °C (1 h). The ketone 7 (125 mg, 0.274 mmol) in THF (3 mL) was added and the solution was brought to reflux. The reaction was very slow, as checked by TLC. After 6 days the product to starting material ratio was 3:1, and the reaction was stopped. Workup with water and ether as in the previous experiment yielded a yellow oil. Silica gel chromatography

(hexane–ether, 9:1) separated the starting material from the product 8. The crude product (86 mg) was dissolved in *p*-dioxane (15 mL) and water (3 mL) and *p*-toluenesulfonic acid (3 mg) was added. The solution was heated under reflux for 30 min (starting material absent by TLC), poured into water, and extracted with ether. The ether was washed with sodium bicarbonate solution and water, dried, and evaporated to give a crude product, which was purified on reverse-phase LC with methanol as eluant to give a white, crystalline solid (41 mg, 34%): mp 143 °C (from MeOH); [α][20.0]$_D$ −27 (*c* 0.76, CHCl$_3$); ^{1}H NMR (360 MHz) (C$_6$D$_6$) δ 0.653 (3, s, C-18 Me), 0.812 (6,t, *J* = 7.4 Hz, C-30/C-31 Me), 0.944 (3, s, C-19 Me), 0.994 (3, s, C-29 Me), 1.015 (3, d, *J* = 6.6 Hz, C-21 Me), 3.4 (1, m, C-3 H), 4.953 (1, s, C-28 H), 5.106 (1, s, C-28 H), 5.35 (1, br, C-6 H); mass spectrum, *m/z* (relative intensity) 440.4054 (M[+], $C_{31}H_{52}O$, 8; calcd 440.4018), 425 (2), 422 (4), 314 (100), 300 (8), 299 (11), 296 (9), 281 (12), 272 (9), 271 (13), 231 (4), 228 (9), 213 (7).

Two Bicyclic C₁₅ Enynes from the Sea Hare *Aplysia oculifera*[1]

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The structures of two geometric isomers (*E*)- and (*Z*)-ocellenyne, isolated from the sea hare *Aplysia oculifera*, were elucidated by chemical degradation and spectral analysis.

Sea hares are gregarious, herbivorous mollusks of the order *Anaspidea* (subclass Opisthobranchia, class Gastropoda). Their global distribution, abundance, intertidal or shallow water habitat, and the large size of some species have made aplysids attractive chemical targets. No comprehensive review of secondary metabolites of sea hares has appeared in print. This is, at least in part, due to the varied dietary origin as well as diverse biogenesis of these compounds. A preferred food of some sea hares is the red algal genus *Laurencia*, renowned for its synthetic capability, which has engendered numerous terpenoid[2a] and nonterpenoid[2b] compounds, many halogenated. One group of nonterpenoid metabolites possesses an unbranched C₁₅ backbone with a conjugated enyne terminus. The first representative of this class of compounds, the oxocin derivative laurencin (1), was described in 1965 by Irie et al.[3]

From the sea hare *Aplysia oculifera* we report isolation and structure determination of two geometrically isomeric enynes, (*E*)- and (*Z*)-ocellenyne (2,3),[4] which possess a novel 2,5-dioxabicyclo[2.2.1]heptane system.

A. oculifera (Adams and Reeve, 1850) were collected on a reef flat near Pupukea, Oahu. We observed that the sea hares were feeding on an unidentified species of *Laurencia*. Extraction of the excised digestive glands from 25 animals and solvent partitioning yielded a lipid fraction, which after chromatographic purification afforded (*E*)-ocellenyne (2, 30 mg) as a colorless oil and (*Z*)-ocellenyne (3, 14 mg) as a colorless solid. Mass spectral analysis showed their composition to be C₁₅H₂₀Br₂O₂.

1   2, 3
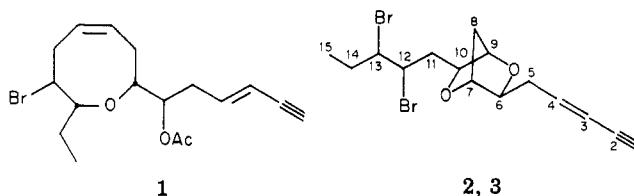
(1) This research was supported by the National Science Foundation (CHE 77-08713); (a) Haumana Minority Biomedical Support Participant 1978/79.
(2) (a) Martin, J. D.; Darias, J. In "Marine Natural Products"; Scheuer, P. J., Ed.; Academic Press: New York, 1978; Vol. 1, Chapter 3. (b) Moore, R. E. *Ibid.*, Chapter 2.
(3) Irie, T.; Suzuki, M.; Masamune, T. *Tetrahedron Lett.* 1965, 1091-1099.

(4) Black-rimmed ocellae (=small eyes) are the characteristic markings of this animal.

Table I. ^{1}H NMR Spectral Data for Ocellenynes 2 and 3^a

H	(E)-ocellenyne (2)		(Z)-ocellenyne (3), CDCl$_3$,^{c}
	CDCl$_3$,^{b}	benzene-d_6,^{b}	
1	2.80 (1 H, d, J = 1.5)	2.59	3.12 (1 H, d, J = 2)
3	5.59 (1 H, dd, J = 15.5, 1.5)	5.51	5.57 (1 H, dd, J = 10.5, 2)
4	6.22 (1 H, ddd, J = 15.5, 7.5, 7.5)	6.19	6.05 (1 H, ddd, J = 10.5, 7, 7)
5α	2.46 (1 H, ddd, J = 13.5, 7.5, 7.5)	2.31	2.74 (1 H, ddd, J = 14, 7, 7)
5β	2.41 (1 H, ddd, J = 13.5, 7.5, 7)	2.16	2.56 (1 H, ddd, J = 14, 7.5, 7)
6	3.85 (1 H, br dd, J = 7.5, 7)	3.38	3.90 (1 H, br dd, J = 7.5, 7)
7	4.35 (1 H, br s)	3.74	4.34 (1 H, br s)
8α 8β	1.90 (2 H, br s)	1.74	1.90 (2 H, br s)
9	4.29 (1 H, br s)	3.84	4.28 (1 H, br s)
10	3.98 (1 H, dd, J = 7, 6.5)	3.96	4.05 (1 H, dd, J = 7, 7)
11α	2.15 (1 H, ddd, J = 14.5, 6.5, 6.5)	2.02	2.13 (1 H, ddd, J = 14, 7, 7)
11β	1.91 (1 H, ddd, J = 14.5, 8, 7)	1.71	1.92 (1 H, ddd, J = 14, 8, 7)
12	4.21 (1 H, ddd, J = 8, 6.5, 2.5)	3.87	4.21 (1 H, ddd, J = 8, 7, 3)
13	4.12 (1 H, ddd, J = 9.5, 3, 2.5)	4.03 (1 H, td, J = 7, 2.5)	4.10 (1 H, ddd, J = 9, 3, 3)
14α	2.07 (1 H, ddq, J = 14.5, 3, 7)		2.05 (1 H, ddq, J = 13, 3, 7)
14β	1.87 (1 H, ddq, J = 14.5, 9.5, 7)	1.76 (2 H, qd, J = 7, 7)	1.85 (1 H, ddq, J = 13, 9, 7)
15	1.02 (3 H, dd, J = 7, 7)	0.79 (3 H, t, J = 7)	1.07 (3 H, dd, J = 7, 7)

^{a} Chemical shift (H, multiplicity, J in hertz). ^{b} Spectrum recorded at 360 MHz. ^{c} Spectrum recorded at 100 MHz.

A terminal acetylene conjugated with an olefin was evident from spectral data of both compounds: IR band at 3300 cm^{-1}, the UV maximum, and ^{1}H NMR data for H-1, H-3, and H-4 (Table I). Proton double resonance experiments confirmed the coupling of the acetylenic protons with H-3 resonating at δ 6.22 (2) and 6.05 (3), respectively. Comparison of all proton shifts (Table I) for compounds **2** and **3** shows that significant differences exist only for H-1, H-4, H-5$_\alpha$, and H-5$_\beta$, which are clearly associated with the geometry of the double bond. In compound **2** the coupling constant of the olefinic protons is 15.5 Hz, indicating E geometry, whereas in **3** the same coupling showed a value of 10.5 Hz, appropriate for Z geometry. The UV maxima also reflect this. Catalytic hydrogenation of **2** and **3** yielded identical hexahydro derivatives **6**, thereby confirming that **2** and **3** are geometric isomers.

The enyne moiety accounts for three of the five unsaturations in C$_{15}$H$_{20}$Br$_2$O$_2$; besides, only ether functions are compatible with the spectral data. Extensive proton double resonance experiments on **2** clarified the remaining two unsaturations. Decoupling of the olefinic proton signal at δ 6.22 (H-4) simplified the coupling patterns at δ 2.46 (1 H, ddd, J = 13.5, 7.5, 7.5 Hz) and δ 2.41 (1 H, ddd, J = 13.5, 7.5, 7 Hz), which are geminally coupled by 13.5 Hz and hence assigned to C-5. Irradiation of a signal at δ 3.85 (H-6) decoupled the two H-5 protons and sharpened a broad singlet resonating at δ 4.35 (H-6). Broad singlets at δ 4.35 (H-7) and 4.29 (H-9) are simultaneously sharpened when a two-proton broad singlet at δ 1.90 (H$_2$-8) is irradiated. Partial structure A accomodates these decoupling data.

Scheme I

Further decoupling experiments revealed the constitution of the remaining six carbons and ten protons. Geminally coupled (J = 14.5 Hz) methylene protons (H$_2$-11) resonating at δ 2.15 (1 H, ddd, J = 14.5, 6.5, 6.5 Hz) and 1.91 (1 H, ddd, J = 14.5, 8, 7 Hz) were decoupled to doublets of doublets upon irradiation of proton signals at δ 3.98 (H-10) and 4.21 (H-12). The signal at δ 4.21 (H-12) also decouples the H-13 pattern at δ 4.12 (1 H, ddd, J = 9.5, 3, 2.5 Hz) by 2.5 Hz. Irradiation of the signal at δ 4.12 (H-13) not only decouples the signal at δ 4.21 (H-12) to a doublet of doublets but also clarifies two complex proton resonances (H$_2$-14) at δ 2.07 (1 H, ddq, J = 14.5, 3, 7 Hz) and 1.87 (1 H, ddq, J = 14.5, 9.5, 7 Hz), which are assigned to nonequivalent methylene protons geminally coupled by 14.5 Hz. The methyl signal at δ 1.02 (H$_3$-15) collapsed to a doublet by irradiating either H-14 proton signal at δ 2.07 or 1.87. Nonequivalence of the methylene protons suggests an adjacent asymmetric carbon. Partial structure B fits these decoupling data.

Partial structures A and B can be combined only as in C in order to accomodate two oxygen and two bromine

atoms sited at six carbons. Furthermore, the two oxygens form independent hetero rings encompassing four carbon atoms and two unsaturations hitherto unaccounted for. ^{1}H NMR data exclude epoxides.

Placement of the four hetero atoms and determination of ring size were accomplished by chemical degradations (Scheme I) and further spectral analysis.

Reaction of **2** with diazabicycloundecene (DBU) in ether for 36 h at room temperature afforded a mixture of two compounds, separable by HPLC into pure **4** (54%) and **5** (42%).

The mass spectrum indicated that **4** was a dehydrobromination product, m/z 310/312 ($C_{15}H_{19}BrO_2$). Structural changes in **4** were easily detected by proton double resonance experiments. Decoupling of proton signals assigned to hydrogens on C-1 to C-9 showed few changes. Protons on C-8 were now magnetically nonequivalent, resonating as an AB system centered at δ 1.93. Irradiation of a signal at δ 3.85 (H-10) caused collapse to doublets of doublets of H_2-11 signals at δ 2.22 (1 H, ddd, J = 13, 7, 7 Hz) and 2.18 (1 H, ddd, J = 13, 7, 6 Hz), which were shown to be geminally coupled by 13 Hz. Both signals, δ 2.22 (H-11$_\alpha$) and 2.18 (H-11$_\beta$), could also be decoupled to doublets of doublets by irradiating an olefinic proton signal at δ 5.65 (H-12); this also caused sharpening of a two-proton signal at δ 2.47 (2 H, br q, J = 7 Hz). The δ 2.47 (H$_2$-14) signal was further decoupled to a broad singlet by irradiating the methyl signal at δ 1.12 (H$_3$-15). These experiments indicated that a double bond exists between C-12 and C-13 with one proton on C-12. C-12 therefore bears a bromine atom in compound **2**.

The structure of the C-10 to C-15 moiety of isomer **4** was further supported by intense mass spectral fragments at m/z 147/149 (25%) and 163 (33%), assigned to fragments D and E.

D

E
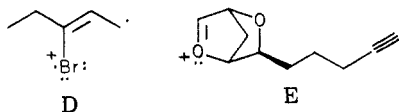
Compound **5** did not show a molecular ion, but familiar fragments clearly indicated that the molecular weight was 310 corresponding to $C_{15}H_{19}BrO_2$. Proton double resonance experiments were helpful in assigning structure **5** and by allowing extrapolation to features of the natural products **2** and **3**. Decoupling data for C-1 through C-9 protons closely paralleled those of the natural product **2** and therefore disclosed no new information. However, significant changes in the proton spin systems of **5** were observed for C-10 to C-15 protons. Irradiation of a proton signal at δ 4.10 (H-10) simplified signals at δ 2.46 (1 H, dd, J = 15, 7 Hz) and 2.38 (1 H, dd, J = 15, 6 Hz) to an AB quartet with geminal coupling of 15 Hz. This nonequivalent methylene group, assigned to C-11, had shifted downfield from δ 2.15 in (E)-ocellenyne (**2**), thus suggesting an allylic environment. No further coupling is seen for the C-11 methylene group, which shows that C-12 is olefinic and bears bromine, in agreement with our interpretation of the DBU reaction that led to **4**. An olefinic proton signal at δ 5.70 (H-13) when irradiated collapsed a two-proton signal at δ 2.17 (2 H, qd, J = 7, 7 Hz) to a quartet. Irradiation of the methyl signal at δ 1.01 (3 H, t, J = 7 Hz) decoupled the methylene signal at δ 2.17 (H$_2$-14) to a doublet. Mass spectral fragments at m/z 163 (47%) and 147/149 (52%) were also seen in **5**, interpreted as E and F. C-13 therefore also bears a bromine atom in **2**.


F
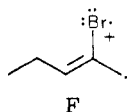
Assignment of the bromine atoms to C-12,13 was supported by debromination of **6** with zinc in ethanol and a trace of acetic acid to olefin **7** in high yield.

Mass spectral data of **7** disclose a formula of $C_{15}H_{26}O_2$, indicating that both bromines were lost with formation of a double bond during the transformation of **6** to **7**. Mass spectral fragments G and H represent m/z 169 and 139 fragments, respectively. The new double bond of **7** has cis


G

H
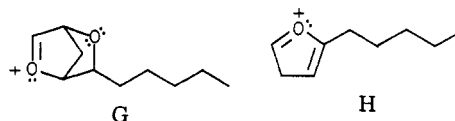
geometry since the two olefinic signals at δ 5.5 and 5.3 are coupled by 10 Hz. The experiment again confirms the vicinal nature of the bromine atoms in **6**. We showed that the debromination reaction had proceeded without side reactions by regenerating **6** from **7** by treating **7** with bromine in carbon tetrachloride, which also produced an uncharacterized stereoisomer of **6**.

Combination of these data allows expansion of part structure C to I. Since neither epoxides nor ketals are

I
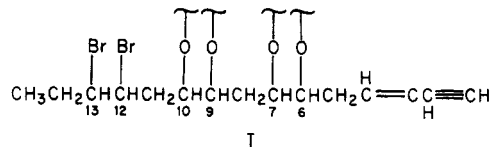
compatible with the spectral data, only two structures may be written, **2** and **8**. The ^{1}H NMR signal of the C-8 protons is a broad singlet at δ 1.90, coupled to two independent vicinal protons, H-7 at δ 4.35 and H-9 at 4.29, suggesting that the C-7,8,9 bridge is common to both oxa rings.[5] The magnetic equivalence of the two methylene protons and their small couplings support this. Structure **8** may be

8

9

10
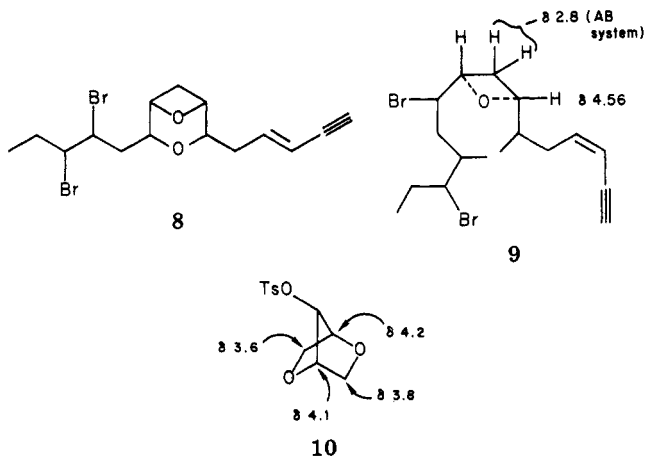
eliminated since the proton resonances in oxetanes are observed at lower field than is the case for **2** and **3**.[6] Laureatin[7] (**9**) is a pertinent model compound for **8**. Compound **10**, on the other hand, is a synthetic 1,4-dioxabicyclo[2.2.1]heptane system with ^{1}H NMR data parallel to those of **2** and **3**.[8]

The stereochemistry of the 12,13-dibromo moiety and of the side chains of the bicyclic system remains to be delineated. Formation of a cis olefin in the zinc debromination reaction requires trans–anti conformation of the bromine atoms. This requirement is satisfied by 12-(S),13(S) or by 12(R),13(R) stereochemistry.

Both alkyl sidechains were assigned exo configuration from the size of the ^{1}H NMR coupling constants between bridgehead (C-7 and C-9) and vicinal (C-6 and C-10)

(5) Jackman, L. M.; Sternhell, S. "Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry", 2nd Ed.; Pergamon Press: Oxford, 1969; p. 288 for pertinent examples in carbocyclic systems.

(6) Reference 5, p 199.

(7) Irie, T.; Izawa, M.; Kurosawa, E. *Tetrahedron Lett.* **1968**, 2091–2096.

(8) Cléophax, J.; Gero, S. D.; Gaudemer, A.; Sepulchre, A. M. *Bull. Soc. Chim. Fr.* **1970**, 4414–4418.

protons, both of which are zero or very nearly so (Table I). Comparable J values in the related bicyclo[2.2.1]hexane system are 0–2 Hz for endo and 3–4 Hz for exo hydrogens.[9] Recent data by Moore et al.[10] for a palytoxin degradation product, which is a dioxabicyclo[3.2.1]octane (11) reinforce the assignment.
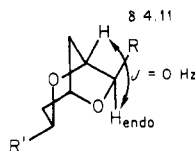
11

Experimental Section

Optical rotations were measured on a Bendix Ericsson ETL-NPL polarimeter calibrated with cholesterol. Mass spectra were recorded on Varian MAT 311 and Finnigan 105 instruments. NMR spectra were determined on Bruker 360 NB, Varian XL-100, and HA-100 spectrometers. IR spectra were recorded on a Perkin-Elmer 467 spectrophotometer and calibrated with polystyrene. UV spectra were recorded on a Beckman ACTA CIII spectrophotometer.

Isolation. Digestive glands of *A. oculifera* were excised from 25 freshly collected animals, homogenized in MeOH, and then soaked for 25 h. The aqueous phase, after MeOH evaporation, was partitioned with CH_2Cl_2. The organic layer after solvent removal yielded a brown oil, 327 mg. The oil was first chromatographed on Sephadex LH-20[11] (CH_2Cl_2/hexanes, 4:1), then on silica gel (hexanes/EtOAc gradient), and finally HPLC on μ-LiChrosorb Si-60[12] (CH_2Cl_2/EtOAc, 1:1), which furnished (*E*)-ocellenyne (2, 30 mg) as a colorless oil $[\alpha]_D^{25}$ +3.21 (c 0.53, CHCl$_3$), and (*Z*)-ocellenyne (3, 14 mg) as a colorless solid, $[\alpha]_D^{25}$ +2.22 (c 0.27, CHCl$_3$). MS analysis revealed identical composition, $C_{15}H_{20}Br_2O_2$, m/z 389.982 (calcd 389.983).

(*E*)-Ocellenyne (2): mass spectrum, m/z 390/392/394 (M$^+$), 325/327/329 (M$^+$ – C$_5$H$_5$), 311/313 (M$^+$ – Br), 295/297/299 (M$^+$ – C$_6$H$_7$O), 269/271/273, 245/247 (M$^+$ – C$_5$H$_5$–HBr), 231 (M$^+$ – Br – HBr), 189/191, 177/179, 165, and 121; IR (CH_2Cl_2) 3300, 3020, 2970, 2920, 2870, 1460, 1440, 1390, 1370, 1300, 1270, 1250, 1225, 1200, 1080, 1050, 950, 920 cm^{-1}, with only a weak acetylenic band at 2100 cm^{-1}; UV (MeOH) 236 nm (ϵ 8800); ^{13}C NMR (25.2 MHz, CDCl$_3$) 141.7, 111.6, 81.8 (3 C), 79.3, 78.2, 76.6, 60.7, 53.5, 40.2, 35.0, 34.7, 29.4, and 12.9 ppm from Me$_4$Si.

(*Z*)-Ocellenyne (3): mass spectrum, m/z 390/394 (M$^+$), 325/327/329 (M$^+$ – C$_5$H$_5$), 311/313 (M$^+$ – Br, 295/297/299 (M$^+$ – C$_6$H$_7$O), 269/271/273, 245/247 (M$^+$ – C$_5$H$_5$ – HBr), 231 (M$^+$ – HBr – Br), 189/191, 177/179, 165, and 121; IR (CH_2Cl_2) 3300, 3010, 2960, 2920, 2870, 2100, 1460, 1440, 1385, 1370, 1295, 1265, 1250, 1220, 1195, 1075, 950, 920 cm^{-1}; UV (MeOH) 230 nm (ϵ 9500).

Dehydrobromo-(*E*)-ocellenynes (4, 5). (*E*)-ocellenyne (7.2 mg) was treated with diazabicycloundecene in ether for 36 h at room temperature. HPLC on LiChrosorb Si-60 (CH_2Cl_2) yielded Δ^{12}-13-bromo (4, 54%) and Δ^{12}-12-bromo (5, 42%) dehydrobromination products.

4: Mass spectrum, m/z 310/312 (M$^+$, C$_{15}$H$_{19}$BrO$_2$), 245/247 (M$^+$ – C$_5$H$_5$), 231 (M$^+$ – Br), 189/191, 163, 147/149; ^{1}H NMR (100

MHz, CDCl$_3$) δ 6.22 (1 H, ddd, J = 16, 7, 7 Hz), 5.65 (1 H, br dd, J = 7, 6 Hz), 5.58 (1 H, br dd, J = 16, 2 Hz), 4.36 (1 H, br d, J = 2 Hz), 4.28 (1 H, br d, J = 1 Hz), 3.86 (1 H, br dd, J = 8, 7 Hz), 3.85 (1 H, br dd, J = 7, 7 Hz), 2.80 (1 H, d, J = 2 Hz), AB system 2.54 (1 H, ddd, J = 15, 8, 7 Hz) and 2.46 (1 H, ddd, J = 15, 7, 7 Hz), 2.47 (2 H, br q, J = 7), AB system 2.22 (1 H, ddd, J = 13, 7, 7 Hz), and 2.18 (1 H, ddd, J = 13, 7, 6 Hz), AB system 1.98 (1 H, br dd, J = 11, 2 Hz), and 1.88 (1 H, br dd, J = 11, 1 Hz), and 1.12 (3 H, t, J = 7 Hz); IR (CH_2Cl_2) 3300, 3010, 2970, 2920, 1460, 1370, 1260, 1240, 1210, 1075, 1050, 950, 925 cm^{-1}; UV (MeOH) 235 nm (ϵ 9350).

5: Mass spectrum, m/z 245/247 (M$^+$ – C$_5$H$_5$), 231 (M$^+$ – Br), 163 (M$^+$ – C$_5$H$_8$Br), 147/149 (C$_5$H$_8$Br); ^{1}H NMR (100 MHz, CDCl$_3$) δ 6.22 (1 H, ddd, J = 16, 7, 7 Hz), 5.70 (1 H, t, J = 7 Hz), 5.59 (1 H, br dd, J = 16, 2 Hz), 4.36 (1 H, br s), 4.35 (1 H, br s), 4.10 (1 H, dd, J = 7, 6 Hz), 3.84 (1 H, br dd, J = 7, 6 Hz), 2.80 (1 H, d J = 2 Hz), AB system 2.50 (1 H, ddd, J = 14, 7, 7 Hz), and 2.40 (1 H, ddd, J = 14, 7, 6 Hz), AB system 2.46 (1 H, dd, J = 15, 6 Hz), and 2.38 (1 H, dd, J = 15, 7 Hz), 2.17 (2 H, qd, J = 7, 7 Hz), 1.90 (2 H, dd, J = 1, 1 Hz), 1.01 (3 H, t, J = 7 Hz); IR (CH_2Cl_2) 3300, 3010, 2960, 2900, 2100, 1450, 1380, 1360, 1295, 1250, 1210, 1070, 950, 920 cm^{-1}; UV (MeOH) 235 nm (ϵ 9200).

Hexahydrocellenyne (6). 2 (4.1 mg) and 3 (2.9 mg) were separately dissolved in ether and hydrogenated over Pt at room temperature and atmospheric pressure. After the mixture was stirred at room temperature for 3 h, silica gel TLC showed a single spot less polar than starting material. Filtration and evaporation of the solvent yielded 4.3 mg (100%) and 2.3 mg (78%) of hexahydrocellenyne (6) from 2 and 3, cleanly without further purification: mass spectrum, m/z 396/398/400 (M$^+$), 352/354/356, 317/319 (M$^+$ – Br), 295/297/299 (M$^+$ – C$_6$H$_{13}$O), 257/259/261, 241/243/245, 237 (M$^+$ – Br – HBr), 217/219, 189/191, 119, 89; ^{1}H NMR (100 MHz, CDCl$_3$) δ 4.37 (1 H, br s), 4.30 (1 H, br s), 4.24 (1 H, m), 4.14 (1 H, m), 4.00 (1 H, br dd, J = 7, 7 Hz), 3.82 (1 H, br dd, J = 7, 6.5 Hz), 2.3–1.8 (3 H, complex), 1.88 (2 H, br s), 1.6 (2 H, m), 1.30 (6 H, complex), 1.07 (3 H, dd, J = 7, 7 Hz), 0.88 (3 H, t, J = 7 Hz); IR (CH_2Cl_2) 2920, 2850, 1460, 1260, 1220, 1050, 950, 910 cm^{-1}.

Hexahydrodedibromocellenyne (7). A 2-mL ethanolic solution of hexahydrocellenyne (6, 10.2 mg) was added to a flask containing Zn dust[13] and a trace of glacial HOAc, suspended in 5 mL of EtOH, and refluxed. After 2 h the reaction mixture was filtered, evaporated, and freeze-dried to yield 5.6 mg (91%) of hexahydrodedibromocellenyne (7). No further purification was needed. 6 was regenerated instantly when 7 (5.6 mg) was treated with Br$_2$/CCl$_4$ at room temperature. Evaporation of the solution yielded 8.3 mg (89%) of a diastereomeric mixture of two debrominated compounds. ^{1}H NMR and MS analysis showed the two-component mixture to be hexahydrocellenyne (6) and a diastereomer of 6.

(9) Reference 5, p 289.
(10) Moore, R. E.; Woolard, F. X.; Bartolini, G. *J. Am. Chem. Soc.* **1980**, *102*, 7370–7372.
(11) Pharmacia Fine Chemicals, Piscataway, NJ.
(12) LiChrosorb is a trademark of E. Merck, Darmstadt, West Germany. The column is made by Dr. H. Knauer and distributed in the U.S. by Unimetrics, Inc., Anaheim, CA.

(13) Zn dust was activated by stirring it in ethanolic HCl solution for 20 min. The Zn dust was filtered and washed with ethanol.