Syntheses and Chiroptical Properties of (−)-Ditwist-brendane and (+)-D_3-Trishomocubane

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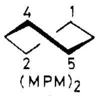
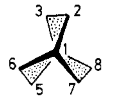
(−)-Ditwist-brendane (tetracyclo[5.2.1.$0^{2,6}$.$0^{4,8}$]decane) (**6**) was prepared by hydrogenolysis of optically active (−)-C_2-bishomocubane (**8**) with known absolute configuration. Synthesis of (+)-D_3-trishomocubane (pentacyclo[6.3.0.$0^{2,6}$.$0^{3,10}$.$0^{5,9}$]undecane) (**27**) is reported, and its absolute configuration is discussed by comparing circular dichroism spectra of the closely related pair of ketones (+)-D_3-trishomocuban-4-one (**26**) and (−)-(1*R*,2*R*,4*S*,6*S*,7*R*,8*S*)-ditwist-brendan-5-one (**14**).

Symmetry number 4 inherent to the molecule of (−)-twistane (D_2 symmetry) (**1**)[1] indicates the presence of four identical twist-boat cyclohexane moieties with a $(MPM)_2$ conformation being disposed around its three C_2 axes. Although this structural feature of **1** can be constructed by bridging the 1,4 and 2,5 positions of the twist-boat cyclohexane (**2**) with two ethano bridges, the twisted bicyclo[2.2.2]octane (**3**) with D_3 symmetry can be regarded as its other generatrix.


(−)-1



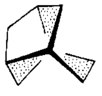
$(MPM)_2$
2



3


4

Freezing the chiral conformation of the bicyclo[2.2.2]octane system (**3**) with either an ethano or methano bridge spanning the 3,6 position gives (−)-twistane (**4**), $[\alpha]_D$ −414°,[1a] or (−)-twist-brendane (C_2 symmetry) (**5**), $[\alpha]_D$ −235°,[2] respectively.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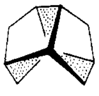
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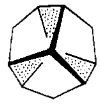
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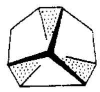
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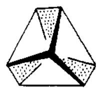
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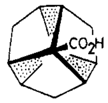


10

Successive diagonal bridging of **5** with CH_2 furnishes ditwist-brendane (C_2 symmetry) (**6**)[3] followed by D_3-trishomocubane (D_3 symmetry) (**7**),[5] which can be regarded as a higher homologue of (−)-C_2-bishomocubane (**8**)[6] whose preparation and absolute configuration have been recently reported from our laboratory.

Among nine theoretically possible trishomocubanes [symmetry (number of members)], C_{3v} (1), C_{2v} (1), C_s (3), D_3 (1), C_2 (1), C_1 (2), generated from cubane (**9**)[7], D_3-trishomocubane (**7**) has the highest chiral symmetry, and its symmetry number 6 necessitates that this molecule is constructed from six identical twist-cyclopentane structural units.

The unique stereochemistry of **7** as well as its rather small size ($C_{11}H_{14}$) appear to render **7** as an attractive C_3 building block (**10**) for constructing high-symmetry chiral molecules with *T*, *O*, and *I* symmetries.[8]

We have been interested in syntheses and chiroptical properties of various high-symmetry chiral (gyrochiral[9]) molecules, and this paper reports syntheses of (−)-ditwist-brendane (**6**) and (+)-D_3-trishomocubane (**27**) as well as their absolute configurations.

Results and Discussion

Synthesis of (−)-Ditwist-brendane (6). Smooth conversion of the C_2-bishomocubane framework into the ditwist-brendane framework via hydrogenolysis of the 8,9 bond has been reported,[4b,c] and this procedure was carried out on (−)-(1*S*,2*S*,3*S*,4*S*,5*R*,7*S*,8*S*,9*R*)-C_2-bishomocubane (**8**) with 5% Pd on carbon, furnishing a 25% yield of (−)-(1*R*,2*R*,4*R*,6*R*,7*R*,8*R*)-ditwist-brendane (**6**): mp 164.5–165.5 °C; $[\alpha]_D$ −233°. Since we desired optically active ditwist-brendan-5-one (**14**) of known absolute configuration as a reference substance for deducing the absolute configuration of (+)-D_3-trishomocubane (**27**), an attempt was made to obtain optically active ditwist-brendane (**6**) via **14** obtained from (+)-C_2-bishomocubane-5,10-dione ethylene ketal (**11**) whose absolute configuration was recently reported from our laboratory.[6] Facile hydrogenolysis with 5% Pd on carbon converted (+)-**11**, $[\alpha]_D$ + 95.9°, into (−)-**13**, and removal of the keto group by Wolff–Kishner reduction followed by hydrolysis of the ethylene ketal protective group afforded (−)-**14**, mp 165–167 °C; $[\alpha]_D$ −181°, Wolff–Kishner reduction of which gave another route to (−)-ditwist-brendane (**6**). (See Scheme I.)

Synthesis of (+)-D_3-Trishomocubane (27). Among various synthetic routes reported for the preparation of trishomocubane (**7**), Barborak's procedure[5e] was our choice because its intermediates appeared to promise facile optical resolution. Rearrangement of Barborak's intermediate **15** afforded (±)-D_3-trishomocubane-4,7-diol, mp 200–203 °C, as a single product, to which the cis configuration **16** was assigned by Barborak for mechanistic reasons. Our observation of two well-resolved equal intensity singlets at δ 1.93 and 1.96 (CH_3CO) exhibited by diacetate **19** supports the cis stereochemistry (C_1 symmetry) of the diol **16** and excludes the two other trans diastereomers **17** and **18** both with C_2 symmetry.

Our various efforts toward optical resolution of diol **16**

Scheme I

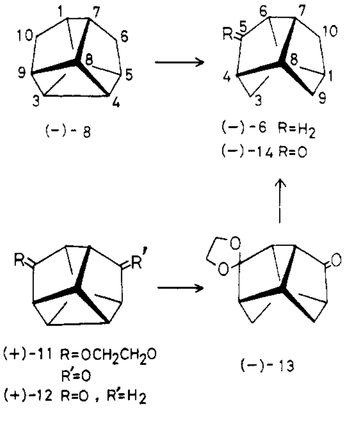
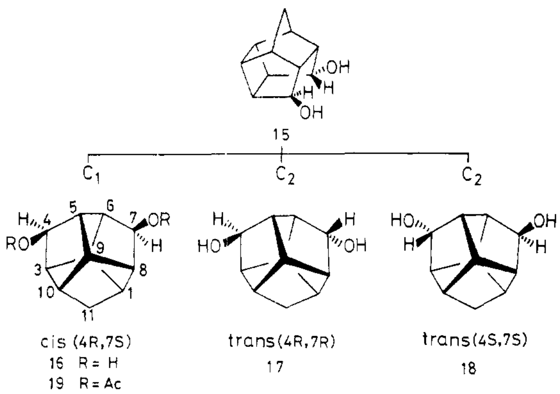


Table I. CD Spectra of (−)-Ditwist-brendan-5-one (14), (+)-D_3-Trishomocuban-4-one (26), and (+)-C_2-Bishomocuban-6-one (12) (in isooctane)

(−)-14		(+)-26		(+)-12	
[θ]	nm	[θ]	nm	[θ]	nm
$+6.67 \times 10^3$ (sh)	289	-5.37×10^3 (sh)	289.3	$+1.22 \times 10^3$ (sh)	298
$+7.04 \times 10^3$	293	-5.60×10^3	292.5	$+1.29 \times 10^3$	301.5
$+6.82 \times 10^3$ (sh)	296.5	-5.27×10^3 (sh)	296.8	$+1.23 \times 10^3$ (sh)	304
$+5.66 \times 10^3$ (sh)	302.5	-4.06×10^3 (sh)	303	$+9.48 \times 10^2$ (sh)	312
$+4.21 \times 10^3$ (sh)	307.5	-2.85×10^3 (sh)	307.5		



15

cis (4R,7S)
16 R = H
19 R = Ac

trans(4R,7R)
17

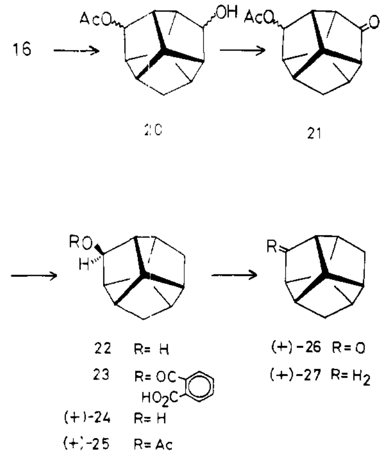
trans(4S,7S)
18

failed, and monoalcohol 22 was chosen as our next candidate for the optical resolution. An equimolar amount of acetyl chloride was added to a pyridine solution of 16, and chromatography of the reaction mixture afforded, besides the diacetate 19 (28%), a mixture of the diastereomeric cis monoacetates 20 (43%) which was directly oxidized with Jones reagent to the keto acetate 21. (See Scheme II.)

Although two acetyl signals (δ 2.00 and 2.07; ratio 4:1) observed in the NMR spectrum of 21 indicated its heterogeneity, Wolff–Kishner reduction of 21 was carried out without isolation of the diastereomers and furnished (±)-D_3-trishomocubanol (22), mp 165–166 °C. Optical resolution of the alcohol 22 was accomplished via the hydrogen phthalate (23) with (+)-2-(1-aminoethyl)naphthalene as the resolving agent. Fractional recrystallization from acetone gave a sparingly soluble salt, $[\alpha]_D$ +65.7°, from which the (+)-alcohol 24, mp 168.5–169.5 °C, $[\alpha]_D$ +143°, was obtained. Collins oxidation converted 24 into (+)-D_3-trishomocubanone (26), mp 163–163.5 °C; $[\alpha]_D$ +83.2°, whose carbonyl group was removed by Wolff–Kishner reduction to give (+)-D_3-trishomocubane (27), mp 148–149 °C; $[\alpha]_D$ +155°.[10]

Chiroptical Properties and Absolute Configurations. Before discussing the absolute configuration of (+)-D_3-trishomocubane (27), it appears pertinent to describe here some of our efforts made to examine its optical purity. To a $CDCl_3$ solution of (+)-D_3-trishomocubanol acetate (25), $[\alpha]_D$ +110°, obtained from the (+)-alcohol 24, $[\alpha]_D$ +143°, tris[3-(trifluoromethylhydroxymethylene)-*d*-camphorato]europium(III) $[Eu(facam)_3]$[11] was added to give a molar ratio of (+)-25/$Eu(facam)_3$ = 1.0:0.15. Observed intensities of the anisochronous CH_3CO signals (ΔΔδ 0.068 ppm) gave a 34:1 enantiomer ratio, which eventually furnishes $[\alpha]_D$ +88.5° and $[\alpha]_D$ +165° as the absolute rotations of 26 and (+)-D_3-trishomocubane (27), respectively.

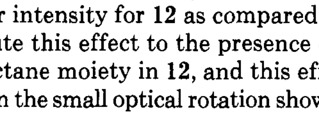
Scheme II



16 → 20 → 21 → 22 R= H; 23 R= OC HO$_2$C; (+)-24 R= H; (+)-25 R=Ac → (+)-26 R=O; (+)-27 R= H_2

Coupled with the synthetic route (Scheme I), the *1S,2S,3S,4S,5R,7S,8S,9R* configuration of (−)-C_2-bishomocubane (8) reported in our preceding paper[6] permits us to assign the *1R,2R,4R,6R,7R,8R* configuration to (−)-ditwist-brendane (6) and *1R,2R,4S,6S,7R,8S* configuration to (−)-ditwist-brendan-5-one (14). From almost exact antipodal n–π^* Cotton curves at 293 nm (Table I) exhibited by (−)-ditwist-brendan-5-one (14) and (+)-D_3-trishomocuban-4-one (26), the enantiomeric environments around these carbonyl groups can be reasonably deduced and indicate the *1R,3R,5R,6S,8R,10S* configuration for (+)-D_3-trishomocuban-4-one (26) and *1R,3R,5R,6R,8R,10R* for (+)-D_3-trishomocubane (27).[10]

These conclusions are further supported by the octant projections (28 and 29) of these ketones which predict a (−)-Cotton effect for (−)-ditwist-brendan-5-one (28) and a (+)-Cotton effect for (+)-D_3-trishomocuban-6-one (29).



(−)-28 (+)-29

Also included in Table I is the CD data for (+)-C_2-bishomocuban-6-one (12), which shares the same optically active precursor (+)-11 with (−)-ditwist-brendan-5-one (14). Since this indicates that 12 and 14 must have almost the same optical purity, it is rather surprising to note a Cotton effect of markedly lower intensity for 12 as compared to 14. We tentatively attribute this effect to the presence of the strained bicyclo[2.2.2]octane moiety in 12, and this effect also seems to be reflected in the small optical rotation shown by its parent hydrocarbon, (−)-C_2-bishomocubane (8), relative to closely related cage-shaped hydrocarbons all possessing the twisted bicyclo[2.2.2]octane system as their characteristic feature (See Table II).

Experimental Section

Infrared spectral data were obtained with a Hitachi EPI-S2 spectrophotometer. Nuclear magnetic resonance spectra were obtained with a JNM-MH-100 spectrometer. Ultraviolet spectra were recorded on a Beckman DB spectrometer. Optical rotations were measured with a JASCO-DIP-SL automatic polarimeter. Circular dichroism data were measured on a JASCO J-40 spectropolarimeter. Elemental analyses were determined on a Yanagimoto CHN-Corder Type II. All melting and boiling points are uncorrected.

(−)-Ditwist-brendane-5,10-dione 5-Ethylene Ketal (13). A solution of (+)-11 (750 mg, 3.67 mmol), $[\alpha]^{14}_D$ + 95.9°,[6] in 75 mL of

Table II. Optical Rotations of (−)-Twist-brendane (5), (−)-Ditwist-brendane (6), (−)-D_3-Trishomocubane (7), and (−)-C_2-Bishomocubane (8)

	(−)-5	(−)-6	(−)-7	(−)-8
$[\alpha]_D$	−235°[a]	−233°[b]	−155°[b]	−33.8°[b]

[a] In ethanol. [b] In chloroform.

methanol was shaken at room temperature in a hydrogenation flask with 370 mg of 5% Pd on carbon at 1 atm of hydrogen. After hydrogen uptake had ceased, the catalyst was removed by filtration. The filtrate was concentrated and the residue was chromatographed on silica gel. Elution with benzene gave a solid which was sublimed at 85 °C (bath temperature, at 5 mm) to yield 316 mg of (−)-**13** (42% yield): mp 53–54 °C; $[\alpha]^{24}{}_D$ −148° (*c* 0.340, $CHCl_3$); IR (KBr) 1750, 1325, 1100, 1055, 1042, and 1010 cm^{-1}; CD (*c* 2.66 × 10^{-2}, isooctane) [θ] (nm) 0 (240), +1.03 × 10^4 (sh) (287.5), +1.11 × 10^4 (292), +1.08 × 10^4 (sh) (295), +8.89 × 10^3 (sh) (301.5), +6.40 × 10^3 (sh) (306.5), 0 (332).

Anal. Calcd for $C_{12}H_{14}O_3$: C, 69.88; H, 6.84. Found: C, 69.67; H, 6.84.

(−)-Ditwist-brendan-5-one (14). A mixture of (−)-**13** (250 mg, 1.21 mmol), 80% hydrazine hydrate (0.2 mL), KOH (0.105 g), and triethylene glycol (2 mL) was heated in an oil bath. During 1.5 h the bath temperature was gradually raised to 190 °C, and this temperature was kept for an additional 3 h. After cooling, a white solid which had formed on the inner wall of the condenser was washed with ether into the flask. The reaction mixture was diluted with water and extracted with ether. The combined ethereal solution was washed with water and dried over $MgSO_4$. The solvent was evaporated to give 0.24 g of an oily product, to which 5 mL of 10% sulfuric acid was added. The mixture was stirred for 24 h at room temperature and extracted with pentane. The extract was washed with saturated $NaHCO_3$ solution and water and dried over $MgSO_4$. Evaporation of the solvent gave a solid which was purified by sublimation at 80–90 °C (bath temperature, at 20 mm) to yield 120 mg of (−)-**14** (67% yield based on **13**); mp 165–167 °C (in a sealed tube); $[\alpha]^{27}{}_D$ −181° (*c* 0.170, $CHCl_3$); IR (KBr) 1760, 1300, 1142, 872, 860, and 745 cm^{-1}; CD (*c* 3.18 × 10^{-2}, isooctane) [θ] (nm) 0 (243), +6.67 × 10^3 (sh) (289), +7.04 × 10^3 (293), +6.82 × 10^3 (sh) (296.5), +5.66 × 10^3 (sh) (302.5), +4.21 × 10^3 (sh) (307.5), 0 (335); UV λ_{max} (isooctane) 291 nm (ϵ 19.2); NMR ($CDCl_3$) δ 1.00–1.35 (m, 1 H), 1.45–1.55 (m, 3 H), 1.75–2.02 (m, 4 H), 2.1–2.6 (m, 4 H).

Anal. Calcd for $C_{10}H_{12}O$: C, 81.04; H, 8.16. Found: C, 80.81; H, 8.07.

(−)-Ditwist-brendane (6). From (−)-ditwist-brendan-5-one (14). To a mixture of KOH (30 mg), 80% hydrazine hydrate (0.1 mL), and triethylene glycol (1 mL) was added (−)-**14** (70 mg, 0.473 mmol). The mixture was heated in an oil bath. During 1.5 h, the bath temperature was gradually raised to 200 °C. When the temperature reached at 160 °C, a white solid was observed to condense on the inner wall of the condenser. After further heating for 3 h at 200 °C, the reaction mixture was cooled to room temperature and the condensed white solid was rinsed with pentane. The reaction mixture was diluted with water and extracted with pentane. The combined pentane extracts were washed with water and dried over $MgSO_4$. Evaporation of the solvent gave a solid which was sublimed at 50 °C (bath temperature, at 20 mm) to yield 28 mg of (−)-**6** (44% yield): mp 164.5–165.5 °C (in a sealed tube); $[\alpha]^{27}{}_D$ −233° (*c* 0.096, $CHCl_3$); IR (KBr) 2920, 1380, 1255, and 810 cm^{-1}.

Anal. Calcd for $C_{10}H_{14}$: C, 89.49; H, 10.51. Found: C, 89.25; H, 10.31.

From (−)-C_2-Bishomocubane (8). A solution of (−)-**8** (70 mg, 0.530 mmol), $[\alpha]^{19}{}_D$ − 33.8°,[6] in 5 mL of methanol was shaken at room temperature in a hydrogenation flask with 30 mg of 5% Pd on carbon at 1 atm of hydrogen. After hydrogen uptake had ceased, the catalyst was filtered off. After the solvent was removed, the residue was sublimed at 50 °C (bath temperature, at 20 mm) to afford 18 mg of **6** (25% yield), $[\alpha]^{27}{}_D$ −232° (*c* 0.101, $CHCl_3$).

The IR spectrum was completely superimposable on the spectrum of (−)-**6** prepared from (−)-**14**.

(±)-D_3-Trishomocubane-4,7-diol (16). (±)-D_3-Trishomocubane-4,7-diol (**16**) was prepared according to Smith and Barborak's procedure.[5e] Recrystallization of the crude diol from acetone gave colorless platelets, mp 200–203 °C (lit.[5e] mp 203–205 °C).

Anal. Calcd for $C_{11}H_{14}O_2$: C, 74.13; H, 7.92. Found: C, 74.01; H, 7.88.

(±)-4,7-Diacetoxy-D_3-trishomocubane (19). To a solution of (±)-**16** (800 mg, 4.49 mmol) in pyridine (3 mL) was added acetic anhydride (1.08 g, 10.8 mmol) at 0–5 °C, and the mixture was stirred for 8 h at room temperature and was then allowed to stand overnight at room temperature. After pouring onto ice, it was acidified with HCl and extracted with ether. The extract was washed successively with 10% HCl, saturated $NaHCO_3$ solution, and water and was dried over $MgSO_4$. After evaporation of the solvent, the residue was distilled to yield 900 mg of **19** (77% yield): bp 165–170 °C (4 mm); IR (neat film) 1732, 1363, 1238, 1041, 942, and 781 cm^{-1}; NMR (CCl_4) δ 1.42 (s, 2 H), 1.93 (s, 3 H), 1.96 (s, 3 H), 2.18 (br s, 6 H), 2.42 (br s, 1 H), 2.53 (br s, 1 H), 4.79 (s, 2 H).

Anal. Calcd for $C_{15}H_{18}O_4$: C, 68.67; H, 6.97. Found: C, 68.91; H, 6.93.

(±)-4-Acetoxy-D_3-trishomocuban-7-one (21). To a solution of (±)-**16** (21.3 g, 0.120 mol) in 100 mL of pyridine was added acetyl chloride (12.2 g, 0.155 mol) and the mixture was kept overnight at room temperature. After pouring onto ice, it was made acidic with HCl and extracted with ether. The extract was washed successively with 10% HCl, saturated $NaHCO_3$ solution, and water and was dried over $MgSO_4$. Evaporation of the solvent gave 41.0 g of an oily product, which was chromatographed on neutral alumina (Woelm, acitivity II). Elutions with benzene gave 8.70 g of diacetate **19** (28% yield), and elutions with ether afforded 11.2 g of monoacetate **20** (43% yield). Final elution with ether–methanol (93:7 volume) gave 4.3 g of recovered diol **16** (20%). Monoacetate **20** (11.2 g, 0.0509 mol) was dissolved in 10 mL of acetone and excess of Jones reagent[12] (19 mL), which was prepared from 5.34 g of chromic trioxide, 4.6 mL of concentrated sulfuric acid, and 15 mL of water, was added slowly to the solution at 0–5 °C. After stirring for 1.5 h at this temperature, the reaction mixture was diluted with water and extracted with ether. The extract was washed with saturated $NaHCO_3$ solution and water and was dried over $MgSO_4$. Evaporation of the solvent gave an oily product which was distilled to afford 10.3 g of **21** (93% yield): bp 115–120 °C (0.25 mm); IR (neat film) 1755, 1730, 1240, and 1050 cm^{-1}; NMR ($CDCl_3$) δ 1.52–1.68 (m, 2 H), 1.8–2.0 (m, 1 H), 2.01 (s, 3 H), 2.0–2.3 (m, 2 H), 2.64 (br s, 5 H), 5.11 (br s, 1 H).

Anal. Calcd for $C_{13}H_{14}O_3$: C, 71.54; H, 6.47. Found: C, 71.84; H, 6.63.

(±)-D_3-Trishomocuban-4-ol (22). A mixture of **21** (4.70 g, 0.0215 mol), KOH (4.30 g), 80% hydrazine hydrate (5.4 mL), and triethylene glycol (30 mL) was heated in an oil bath. During 1 h, the bath temperature was gradually raised to 200 °C and this temperature was then kept for an additional 4.5 h. After cooling to room temperature, the reaction mixture was diluted with water and extracted with ether. The extract was washed successively with 10% HCl, saturated $NaHCO_3$ solution, and water and was then dried over $MgSO_4$. Evaporation of the solvent gave a solid which was recrystallized from *n*-hexane to afford 2.80 g of **22** (80% yield): mp 165–166 °C (in a sealed tube); IR (KBr) 3300, 1348, 1298, 1275, 1078, and 1065 cm^{-1}.

Anal. Calcd for $C_{11}H_{14}O$: C, 81.44; H, 8.70. Found: C, 81.22; H, 8.72.

Optical Resolution of D_3-Trishomocuban-4-ol (22). Phthalic anhydride (18.7 g, 0.126 mol) was added to a solution of **22** (20.4 g, 0.126 mol) in 150 mL of pyridine and the mixture was stirred for 4 h with ice cooling. After standing overnight at room temperature, the reaction mixture was poured onto ice and made acidic with HCl. It was extracted with ether, and the extract was washed with 10% HCl and water. Drying over $MgSO_4$, followed by removal of the solvent, gave 37.3 g of viscous oily hydrogen phthalate (**23**), which was dissolved in 1.5 L of acetone without further purification. To this solution was added slowly a solution of (+)-2-(1-aminoethyl)naphthalene (20.5 g, 0.120 mol) in 200 mL of acetone. After boiling for 2 h, acetone (~1 L) was removed and the residual solution was allowed to stand overnight at room temperature. The deposited solid was collected by filtration to give 29.4 g of the hydrogen phthalate salt with (+)-amine, $[\alpha]^{25}{}_D$ +32.3° (*c* 0.510, EtOH), and the filtrate was reserved for isolation of (−)-hydrogen phthalate (**23**) (vide infra).

(+)-Hydrogen Phthalate (23). Several fractional recrystallizations of the salt from acetone yielded 12.5 g of the dextrorotatory salt: mp 188–189 °C; $[\alpha]^{26}{}_D$ +65.7° (*c* 0.347, EtOH). This salt was mixed with 250 mL of 5% HCl and the mixture was stirred for 6 h at room temperature. After drying over $MgSO_4$, the solvent was evaporated to give 7.96 g of the dextrorotatory hydrogen phthalate (**23**) [21% from (±)-hydrogen phthalate (**23**)], $[\alpha]^{23}{}_D$ +84.5° (*c* 0.638, $CHCl_3$), which was recrystallized from benzene to yield 6.88 g of **23**: mp 151–152 °C; $[\alpha]^{24}{}_D$ +86.5° (*c* 0.600, $CHCl_3$).

Anal. Calcd for $C_{19}H_{18}O_4$: C, 73.53; H, 5.85. Found: C, 73.68; H, 5.82.

(−)-Hydrogen Phthalate (23). The filtrate separated from the salt of (+)-hydrogen phthalate was concentrated and the crystalline product was recrystallized from acetone to give the levorotatory salt (3.60 g), $[\alpha]^{24}{}_D$ −16.2° (*c* 0.320, EtOH), which was treated with 5% HCl to yield 2.31 g of (−)-hydrogen phthalate (**23**), $[\alpha]^{20}{}_D$ −35.3° (*c* 0.533, $CHCl_3$).

(+)-*D*$_3$-Trishomocuban-4-ol (24). (+)-Hydrogen phthalate (**23**) (6.88 g, 0.0222 mol), $[\alpha]^{24}{}_D$ +86.5°, was stirred for 5 h at room temperature with 5% KOH aqueous solution (200 mL), and the reaction mixture was then extracted with ether. The extract was washed successively with 10% HCl, saturated $NaHCO_3$ solution, and water and was dried over $MgSO_4$. Evaporation of the solvent gave 3.40 g of **24**, $[\alpha]^{20}{}_D$ +139° (*c* 0.364, EtOH), which was recrystallized five times from *n*-hexane to afford 2.68 g of (+)-**24** (74% yield): mp 168.5–169.5 °C (in a sealed tube); $[\alpha]^{25}{}_D$ +143° (*c* 0.590, EtOH); IR (KBr) 3300, 1348, 1298, 1280, 1078, and 1065 cm^{-1}.

Anal. Calcd for $C_{11}H_{14}O$: C, 81.44; H, 8.70. Found: C, 81.30; H, 8.73.

(+)-4-Acetoxy-*D*$_3$-trishomocubane (25). To a solution of (+)-**24** (400 mg, 2.46 mmol) in 1.5 mL of pyridine was added acetyl chloride (290 mg, 3.67 mmol) with ice cooling, and the mixture was stirred for 5 h at this temperature. After standing overnight at room temperature, the reaction mixture was poured onto ice. It was made acidic with HCl and extracted with ether. The extract was washed successively with 10% HCl, saturated $NaHCO_3$ solution, and water and was dried over $MgSO_4$. The solvent was evaporated and the residue was distilled to yield 402 mg of (+)-**25** (80% yield): bp 108–109 °C (4 mm); $[\alpha]^{24}{}_D$ +110° (*c* 0.797, $CHCl_3$); IR (neat film) 1735, 1245, and 1048 cm^{-1}; NMR ($CDCl_3$) δ 1.36 (s, 4 H), 1.92 (s, 3 H), 2.07 (br s, 7 H), 2.42 (br s, 1 H), 4.75 (s, 1 H).

Anal. Calcd for $C_{13}H_{16}O_2$: C, 46.44; H, 7.90. Found: C, 46.47; H, 7.89.

(+)-*D*$_3$-Trishomocuban-4-one (26). To a suspension of pyridinium chlorochromate[13] (2.80 g, 13.1 mmol) in dry methylene chloride (8 mL) was added a solution of (+)-**24** (1.00 g, 6.17 mmol) in dry methylene chloride (17 mL) and the mixture was stirred for 1.5 h at room temperature. The organic solution was separated by decantation and the inorganic residue was rinsed with ether. Combined extracts were washed successively with 10% HCl, saturated $NaHCO_3$ solution, and water and was dried over $MgSO_4$. After evaporation of the solvent, the residue was chromatographed on neutral alumina (Woelm, activity II). Elutions with pentane–ether (9:1 v/v) gave a solid which was sublimed at 70–80 °C (bath temperature, at 25 mm) to afford 770 mg of (+)-**26** (78% yield): mp 163–163.5 °C (lit.[5c] racemate mp 163–164 °C); $[\alpha]^{25}{}_D$ +83.2° (*c* 0.650, EtOH); IR (KBr) 1768, 1748, 1160, and 890 cm^{-1}; NMR ($CDCl_3$) δ 1.46 (s, 2 H), 1.61 (s, 2 H), 1.78 (br s, 2 H), 2.40 (br s, 6 H); CD (*c* 3.30×10^{-2}, isooctane) $[\theta]$ (nm) 0 (239), -5.37×10^3 (sh) (289.3), -5.60×10^3 (292.5), -5.27×10^3 (sh) (296.8), -4.06×10^3 (sh) (303), -2.85×10^3 (sh) (307.5), 0 (334); UV λ_{max} (isooctane) 272 nm (sh) (ϵ 12.7), 285.5 (ϵ 17.5).

Anal. Calcd for $C_{11}H_{12}O$: C, 82.46; H, 7.55. Found: C, 82.25; H, 7.54.

(+)-*D*$_3$-Trishomocubane (27). A mixture of (+)-**26** (250 mg, 1.56 mmol), KOH (300 mg), 80% hydrazine hydrate (420 mg), and triethylene glycol (1.5 mL) was heated in an oil bath. During 100 min, the bath temperature was gradually raised to 200 °C and this temperature was kept for an additional 3 h. A white solid was observed to condense on the inner wall of the condenser during this time. After cooling to room temperature, the white solid was washed with ether and the reaction mixture was poured into ice water. After extraction with ether, combined ethereal solutions were washed with 10% HCl, saturated $NaHCO_3$ solution, and water and was dried over $MgSO_4$. Evaporation of the solvent gave a semisolid which was chromatographed on neutral alumina (Woelm, activity II). Elution with pentane afforded a solid which was sublimed at 130 °C (bath temperature, at 30 mm) to yield 150 mg of (+)-**27** (66% yield): mp 148–149 °C (in a sealed tube) (lit.[5c] mp 149–151 °C; lit.[10] mp 149 °C); $[\alpha]^{24}{}_D$ +155° (*c* 0.760, $CHCl_3$); IR (KBr) 2940, 2860, 1460, 1295, 1275, 965, and 765 cm^{-1}; NMR ($CDCl_3$) δ 1.32 (s, 6 H), 1.94 (br s, 8 H).

Anal. Calcd for $C_{11}H_{14}$: C, 90.35; H, 9.65. Found: C, 90.11; H, 9.57.

Registry No.—**5,** 42070-69-9; **6,** 64727-80-6; **7,** 61473-77-6; **8,** 62928-75-0; **11,** 62928-73-8; **12,** 62928-74-9; **13,** 64706-11-2; **14,** 64753-80-6; **16,** 64727-81-7; **19,** 64727-82-8; **20,** isomer I, 64706-12-3; **20** isomer II, 64727-83-9; **21,** 64706-13-4; **22,** 64706-14-5; (+)-**23,** 64706-15-6; (+)-**23** (+)-2-(1-aminoethyl)naphthalene salt, 64727-84-0; (−)-**23,** 64727-85-1; (−)-**23** (+)-2-(1-aminoethyl)naphthalene salt, 64783-67-1; **24,** 61473-81-2; **25,** 64706-16-7; **26,** 61473-82-3; **27,** 61473-83-4; acetic anhydride, 108-24-7; acetyl chloride, 75-36-5; (+)-2-(1-aminoethyl)naphthalene, 3906-16-9; phthalic anhydride, 85-44-9.

References and Notes

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(3) The IUPAC name is tetracyclo[5.2.1.0^{2,6}.0^{4,8}]decane.[4] We herein give this hydrocarbon the trivial name "ditwist-brendane", since it can be conceptually constructed by overlapping two twist-brendanes to generate a new C_2 axis.

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