Anal. Calcd for $C_{18}H_{18}N_4$: C, 74.45; H, 6.25. Found: C, 74.29; H, 6.30.

4f: IR (TF) 4.72 (sh) and 4.78 μm; NMR ($CDCl_3$) δ 1.60 (s, 3, CH_3); mass spectrum (70 eV) *m/e* (rel intensity) 122 (13), 94 (16), 69 (100), 67 (71), and 53 (31).

Anal. Calcd for $C_8H_{12}N_4$: C, 58.21; H, 7.37. Found: C, 58.38; H, 7.42.

4g: mp 64–66 °C; IR (TF) 4.76 μm; NMR ($CDCl_3$) δ 0.94 and 1.01 (two s, 6, C-18 and C-19 angular CH_3), 1.69 (s, 3, C-21 CH_3), 2.75 (t, J = 3 Hz, 1, C-6α H), and 3.30 (s, 3, OCH_3); mass spectrum (70 eV) *m/e* (rel intensity) 382 (50, M^+), 368 (52), 351 (81), 328 (100), 159 (19), and 119 (24).

Anal. Calcd for $C_{23}H_{34}N_4O$: C, 72.21; H, 8.96. Found: C, 72.20; H, 8.97.

2-Cyclopentyl-2-iodopropanenitrile (5a). To 486 mg (3.0 mmol, 1.5 equiv) of iodine monochloride at −10 °C under a nitrogen atmosphere was added 474 mg (2.0 mmol) of *N-tert*-butyldimethylsilylcyclopentylmethylketenimine[10] in 2 mL of anhydrous THF. This dark brown solution was stirred for 1 h at 25 °C, diluted with 25 mL of ether, and washed with 25 mL of water. The aqueous layer was reextracted with 25 mL of ether, and the combined organic layers were washed with two 25-mL portions of a saturated sodium thiosulfate solution, with two 25-mL portions of water, and with 25 mL of brine and dried over anhydrous $MgSO_4$. Evaporation of the solvent afforded 542 mg of a brown oil which was chromatographed on a 20 × 20 (2 mm thick) Merck silica gel F254 preparative layer plate in 5:1 hexane–ether. A band (R_f 0.57) was eluted to afford 182 mg (37%) of **5a:**[8] IR (TF) 4.50 μm; NMR ($CDCl_3$) δ 2.25 (s, 3, CH_3); mass spectrum (70 eV) (rel intensity) 127 (3), 122 (93), 105 (11), 95 (63), 80 (21), and 67 (100).

2-Cyclopentyl-2-hydroxypropanenitrile Mesylate (5b). The procedure of Crossland[11] was repeated using 139 mg (1.0 mmol) of 2-cyclopentyl-2-hydroxypropanenitrile, 126 mg (1.1 mmol, 1.1 equiv) of methanesulfonyl chloride, and 111 mg (1.1 mmol, 1.1 equiv) of triethylamine in 3 mL of anhydrous dichloromethane at 0 °C to afford 195 mg (90%) of **5b:** IR ($CHCl_3$) 7.32 and 8.41 μm; NMR ($CDCl_3$) δ 1.94 (s, 3, CH_3) and 3.16 (s, 3, SO_2CH_3); mass spectrum (70 eV) *m/e* (rel intensity) 138 (11), 122 (62), 95 (86), 79 (18), and 69 (100).

Acknowledgment. We wish to thank the National Institutes of Health (GM-22978-02) and the National Science Foundation (CHE76-16788) and G. D. Searle and Co. for their generous financial support. One of us (D.L.S.) wishes to thank the AMC Cancer Research Center, Lakewood, Colo. for a fellowship. We also wish to thank Union Carbide for a gift of peracetic acid and Mr. Richard W. Olsson for technical assistance.

Registry No.—**5a**, 65516-55-4; **5b**, 65516-56-5; chloromethyl phenyl sulfone, 7205-98-3; *N-tert*-butyldimethylsilylcyclopentylmethylketenimine 65516-57-6; 2-cyclopentyl-2-hydroxypropanenitrile, 65516-58-7.

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Alternative Route to Three of the Four Terpenoid Components of the Boll Weevil Sex Pheromone

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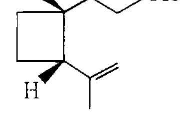
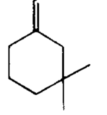
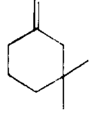
The ecological imbalance and environmental pollution due to insectiside residues has stimulated a great interest in the synthesis of pheromones, since they may provide a generally nontoxic method of biological control of insect populations.[1] A pheromone complex emitted by live male boll weevils (*Anthonomus grandis* Boheman) comprising the four terpenoid compounds (+)-*cis*-2-isopropenyl-1-methylcyclobutaneethanol (**1**), (*Z*)-3,3-dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol (**2**), (*Z*)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde (**3**), and (*E*)-3,3-dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde (**4**) were identified and first synthesized by Tumlinson et al.[2] We would like to report a simple sequence of reactions which afford the synthesis of alcohol **2** and aldehydes **3** and **4** in high yield from readily available starting materials.



1



2



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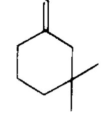
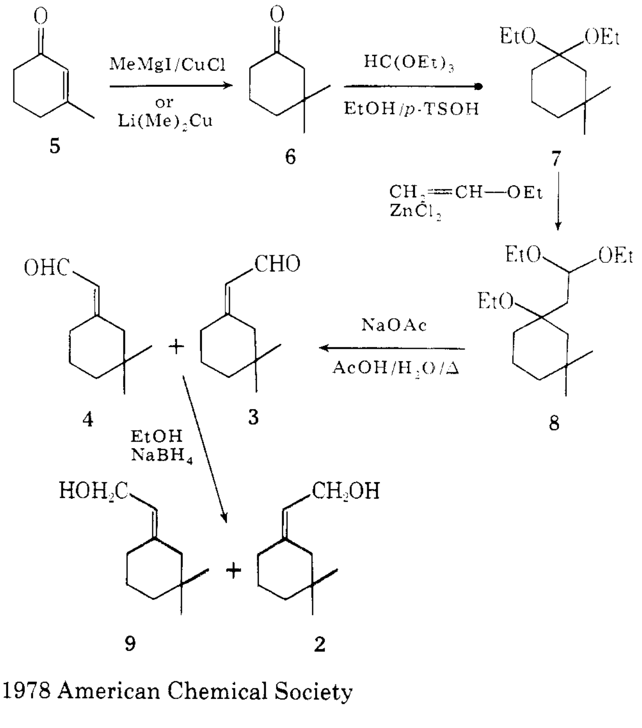


4

Scheme I shows the synthesis of three cyclohexyl constituents of the boll weevil pheromone. 3,3-Dimethylcyclohexanone (**6**), utilized in previous syntheses,[3-5] was prepared from commercially available 3-methyl-2-cyclohexen-1-one by conjugate addition.[6] Reaction of ketone **6** with triethyl orthoformate in anhydrous ethanol and a catalytic amount of *p*-toluenesulfonic acid afforded 3,3-dimethylcyclohexanone diethyl ketal (**7**) in 87% yield. Treatment of ketal **7** with ethyl vinyl ether in a 10% $ZnCl_2$–ethyl acetate solution[7] gave the acetal **8** in 94% yield. Hydrolysis of compound **8** with glacial acetic acid, sodium acetate, and water afforded the isomeric aldehydes **3** and **4**, in 84% yield.[8] Thus, aldehydes **3** and **4** were prepared in 69% overall yield from starting material **6**. Reduction of a mixture of aldehydes 3 and 4 with $NaBH_4$ in

Scheme I



ethanol gave the corresponding mixture of *Z* alcohol **2** and its *E* isomer **9** in a quantitative yield. Aldehydes **3** and **4** could be separated[9] prior to this step or alcohols **2** and **9** would have to be isolated after reduction.

Experimental Section

All boiling points are uncorrected. Infrared spectra were determined with a Perkin-Elmer Model 137 spectrometer. NMR spectra were determined in deuteriochloroform solution on Varian Associates spectrometers, Models A-60 or XL-100. Line positions are given in δ scale, with tetramethylsilane as an internal standard. Mass spectra were recorded on an Atlas CH-4B or Associated Electrical Industries MS-902 spectrometer, high resolution measurements being determined with the latter instrument.

3,3-Dimethylcyclohexanone Diethyl Ketal (7). 3,3-Dimethylcyclohexanone (**6**) (6.54 g, 51.0 mmol), triethyl orthoformate (8.98 g, 60.6 mmol), and *p*-toluenesulfonic acid (6 mg) in 38 mL of anhydrous ethanol were stirred at room temperature for 64 h. Enough ethanolic NaOEt was added to neutralize the reaction mixture and the latter was concentrated under vacuum. Fractional distillation through a spinning-band column gave 9 g (87%) of pure 3,3-dimethylcyclohexanone diethyl ketal (**7**): bp 82–83 °C (13 mm); IR (neat) 1385, 1359 ($-C(CH_3)_2$), 1195, 1174, 1119, 1093, 1058 cm^{-1} (COCOC); ^1H NMR ($CDCl_3$) δ 0.95 (s, 6 H, geminal CH_3), 1.14 (t, 6 H, J = 7 Hz, CH_3CH_2-), 1.49 (s, 2 H, $(RO)_2CCH_2C(CH_3)_2$), 3.45 (q, 4 H, J = 7 Hz, CH_3CH_2-); mol wt 200.1777 (calcd for $C_{12}H_{24}O_2$: 200.1776).

2-(1-Ethoxy-3,3-dimethylcyclohexyl)-1,1-diethoxyethane (8). In a three-necked flask equipped with a rubber septum and a dry ice condenser protected with a calcium chloride tube are placed 3,3-dimethylcyclohexanone diethyl ketal (**7**) (7.37 g, 36.9 mmol) and 3 mL of a solution of 10% $ZnCl_2$ in ethyl acetate. The mixture was stirred and maintained at a temperature of 45 °C while 3.8 mL of ethyl vinyl ether (40.5 mmol) was added dropwise with a syringe. After the addition was completed the mixture was stirred for 2 h at 45–50 °C (bath temperature) and then allowed to come to room temperature. The mixture was diluted with ether and washed with a solution of 5% NaOH and the ethereal layer was dried over Na_2CO_3. Filtration and removal of the solvent gave 9.45 g (94%) of 2-(1-ethoxy-3,3-dimethylcyclohexyl)-1,1-diethoxyethane (**8**), which was purified by distillation using a spinning band column: bp 79–80 °C (0.5 mm); IR (neat) 2950, 1389, 1370, 1183, 1124, and 1064 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.86 and 1.05 (two singlets for geminal methyl group), 1.12 and 1.18 (t, 3 H, CH_3CH_2O), 1.74 (d, 2 H, J = 4 Hz, $EtOCCH_2CH(OEt)_2$), 3.2–38 (m, 6 H, OCH_2CH_3), 4.68 (t, 1 H, J = 4 Hz, $CH(OEt)_2$).

Preparation of (*Z*)-3,3-Dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde(3) and (*E*)-3,3-Dimethyl-$\Delta^{1,\alpha}$-cyclohexaneacetaldehyde (4). To acetal **8** (950 mg, 3.4 mmol) dissolved in 10 mL of glacial acetic acid and 0.77 mL of water was added 1.1 g of sodium acetate. The reaction mixture was stirred and heated for 3 h at 95 °C under an atmosphere of nitrogen. After cooling the resulting mixture was poured into ice, basified by careful addition of solid $NaHCO_3$, and extracted with ether. The combined extracts were washed with water and 5% aqueous $NaHCO_3$ and dried over anhydrous Na_2CO_3. Filtration and removal of the solvent gave 450 mg (84%) of a mixture[7] of aldehydes **3** and **4**, showing properties consistent with those reported by Tumlinson:[2] IR (neat) 1681 and 1639 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.96 (s, 6 H, geminal CH_3). 2.24 (t, 2 H, $-CH_2-$ trans to $-CHO$), 2.50 (s, 2 H, $-CH_2-$ cis to $-CHO$), 5.92 (d, 1 H, J = 8 Hz, $-C{=}CH-$), and 9.98 (d, 1 H, J = 8 Hz, $-CHO$) were assigned to **3**, while those peaks at 0.93 (s, 6 H geminal CH_3), 2.08 (s, 2 H, $-CH_2-$ trans to $-CHO$), 2.68 (t, 2 H, $-CH_2-$ cis to $-CHO$), 5.78 (d, 2 H, J = 8 Hz, $-C{=}CH-$), and 10.02 (d, 1 H, J = 8 Hz, $-CHO$) were assigned to **4**. NMR peaks at 1.2–1.9 were common to both isomers; mol wt 152.1206 (calcd for $C_{10}H_{16}O$: 152.1201).

Preparation of the Isomeric Alcohols (*Z*)-3,3-Dimethyl-$\Delta^{1,\beta}$-cyclohexaneethanol (2) and (*E*)-3,3-Dimethyl-($\Delta^{1,\beta}$-cyclohexaneethanol (9). A mixture of 400 mg of aldehydes 3 and 4 (6:4 ratio) in 20 mL of absolute ethanol and 400 mg of $NaBH_4$ was stirred at ambient temperature for 1 h. The reaction mixture was hydrolyzed with water and extracted with CH_2Cl_2. The combined extracts were washed with water and dried over anhydrous $MgSO_4$. Filtration and removal of the solvent gave the isomeric alcohols **2** and **9** in a quantitative yield, showing properties consistent with those reported by Tumlinson:[2] IR (neat) 3400, 1667, 1075, 1031, 1000 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.90 (s, 6 H, geminal CH_3), 1.92 (s, 2 H, $-CH_2-$ cis to $-CH_2OH$), 2.07 (t, 2 H, $-CH_2-$ trans to $-CH_2OH$), 4.12 (d, 2 H, J = 7 Hz, $-CH_2OH$), and 5.48 (t, 1 H, J = 7 Hz, $-C{=}CH-$) were assigned to **2**, while those at 0.87 (s, 6 H, geminal CH_3), 1.89 (s, 2 H, $-CH_2-$ trans to $-CH_2OH$), 2.12 (t, 2 H, $-CH_2-$ cis to $-CH_2OH$), 4.14 (d, 2 H, J = 7 Hz, $-CH_2OH$), and 5.32 (t, 1 H, J = 7 Hz, $-C{=}CH-$) were assigned to **9**. NMR peaks at 1.2–1.8 were common to both isomers; mol wt 154.1341 (calcd for $C_{10}H_{18}O$: 154.1357).

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Registry No.—**2,** 26532-23-0; **3,** 26532-24-1; **4,** 26532-25-2; **6,** 2979-19-3; **7,** 65392-27-0; **8,** 65392-28-1; **9,** 30346-27-1; triethyl orthoformate, 122-51-0; ethyl vinyl ether, 109-92-2.

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Cobalt-Catalyzed Oxidation of Isotopically Labeled Cyclohexanone

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A large body of literature exists covering various aspects of metal-catalyzed oxidation of cyclohexanone or cyclohexane to yield predominantly adipic acid.[1–4] We report herein results of studies on cobalt-catalyzed oxidations of isotopically labeled cyclohexanone. Of the numerous by-products formed, glutaric and succinic acids are formed in 10–20% yields. We examined the fate of cyclohexanone labeled at the carbonyl carbon with ^{14}C and with ^{13}C to try to resolve conflicting mechanistic proposals for the formation of glutaric and succinic acids.

The percentage retention of the carbonyl carbon from labeled cyclohexanone in glutaric and succinic acid products was 91% in glutaric acid and 87% in succinic acid as shown in Table I.

The high retention of C-1 from labeled cyclohexanone is not consistent with a proposal that glutaric acid arises by exclusive

Table I. Oxidation of [1-^{14}C]- and [1-^{13}C]Cyclohexanone (K): Percent Retention of C-1 by Glutaric and Succinic Acids

K	% retention of C-1		% K conversion	% yields from K		
	Glutaric/ adipic	Succinic/ adipic		Adipic	Glutaric	Succinic
[1-^{14}C]	88	82	63	18	5	0.4
[1-^{13}C]	96	84	62	23	4	0.5
[1-^{13}C]	88	94	34	37	8	1.1
Average	91	87				

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