at 1720 cm^{-1} suggested the presence of 5-benzylneopinone rather than 5-benzylcodeinone.

5-Benzyl-14-hydroxycodeinone (8). 5-Benzylthebaine (**5**, 200 mg, 0.5 mmol) in 97% formic acid (2 mL) was treated with 30% H_2O_2 (0.1 mL) at 0 °C. After 30 min the mixture was heated at 55 °C for 45 min, cooled, poured into ice, and neutralized with ammonia. Extractive workup (chloroform–water) gave a crude brown gum, which was chromatographed on silica, eluting with 5% MeOH in chloroform to yield 5-benzyl-14-hydroxycodeinone (**8**, 48 mg, 24%). A sample crystallized from ethyl acetate for analysis had mp 178–179 °C: IR ν 3330, 2910, 2840, 1690, 1630, 1600, 1450, 1360, 1130, 1100, 1000, and 950 cm^{-1}; NMR δ 1.39–1.45 (m, 1 H), 2.1–2.2 (m, 1 H), 2.35 (s, 3 H, N-Me), 2.36–2.5 (m, 3 H), 2.85 (m, 1 H), 3.11 (d, 1 H, J = 18.5 Hz), 3.21, 3.53 (AB, 2 H, J = 14.5 Hz), 6.01 (d, 1 H, J = 10 Hz, C_8-H), 6.44 (d, 1 H, J = 10 Hz, C_7-H), 6.50, 6.58 (AB q, 2 H, J = 8 Hz, aromatic H), 7.2 (m, 5 H, aromatic H); $[\alpha]^{23}_D$ −233° (c 0.66, 95% alcohol). Anal. Calcd for $C_{25}H_{25}NO_4$: C, 74.42; H, 6.25; N, 3.47. Found: C, 74.42; H, 6.64; N, 3.56.

5-Carbethoxythebaine (9). To a solution of the thebaine anion, prepared as reported earlier[1] from 1.533 g of thebaine, was added 0.75 g of ethyl chloroformate (distilled and stored over $CaCO_3$). Only a slight change in color was observed. After being stirred a further 20 min at −78 °C, the solution was allowed to come to room temperature over 2 h, during which the color changed to orange-yellow. Water (5 mL) was added, and most of the solvent was removed at diminished pressure. The yellow-brown residue was taken up in chloroform, washed twice with water, filtered through anhydrous sodium sulfate, and concentrated. The residue was subjected to MPLC on silica gel (elution with 2% methanol in chloroform) to give 1.32 g, 86% based on unrecovered thebaine, of 5-carbethoxythebaine (**9**) as a pale yellow foam; 386 mg of unreacted thebaine was also recovered. Attempts to crystallize **9** were unsuccessful: IR ν 2950, 1740, 1600, 1430, 1220, 1150, 1100, 980, and 900 cm^{-1}; NMR δ 1.27 (t, 3 H, J = 7 Hz, ester methyl), 2.31 (s, 3 H, N-Me), 3.52 (s, 3 H, C_6-OMe), 3.81 (s, 3 H, C_3-OMe), 3.82 (q, 2 H, J = 7 Hz, ester methylene), 5.1 (d, 1 H, J = 6 Hz, C_8-H), 5.53 (d, 1 H, J = 6 Hz, C_7-H), 6.58 (m, 2 H, aromatic H); $[\alpha]^{23}_D$ −395° (c 0.63, 95% alcohol). Anal. Calcd for $C_{22}H_{25}NO_5$: C, 68.91; H, 6.57; N, 3.65. Found: C, 68.67; H, 6.74; N, 3.55.

5-Carbethoxycodeinone (10). 5-Carbethoxythebaine (686 mg, 1.79 mmol) in 50 mL of 3 M formic acid was treated with mercuric acetate (55 mg) under N_2 at room temperature. Stirring at room temperature continued for 7 days, with 25 mg of fresh mercuric acetate added at the end of each 24-h period. Saturated potassium carbonate solution (60 mL) was added slowly, and the mixture was extracted with chloroform four times. The combined chloroform extracts were washed with water, filtered through anhydrous sodium sulfate, and concentrated to yield a reddish brown gum. This was chromatographed on silica (elution with 5% methanol in chloroform) to give 348 mg, 52.7%, of 5-carbethoxycodeinone (**10**) as a pale yellow solid after crystallization from anhydrous ether at −5 °C: mp 152–154 °C; IR ν 1740 (ester carbonyl) and 1690 (enone) cm^{-1}; NMR δ 1.3 (t, 3 H, J = 7 Hz, ester methyl), 2.32 (s, 3 H, N-CH_3), 3.83 (s, 3 H, C_3-OMe), 4.33 (q, 2 H, J = 7 Hz, ester methylene), 6.02 (d of d, 1 H, J_{14} = 3 Hz, J_8 = 11 Hz, C_7-H), 6.69 (m, 3 H, C_8-H and aromatic protons); $[\alpha]^{23}_D$ −255° (c 0.60, 95% alcohol). Anal. Calcd for $C_{21}H_{23}NO_5$: C, 68.28; H, 6.29; N, 3.79. Found: C, 68.15; H, 6.40; N, 3.62.

Reduction of 5-Carbethoxycodeinone with Sodium Borohydride (11). 5-Carbethoxycodeinone (**10**, 348 mg, 0.943 mmol) in 5 mL of methanol was treated with sodium borohydride (180 mg) at −5 °C. TLC indicated complete disappearance of starting material and formation of several products. The reaction was quenched by aqueous ammonium chloride and extracted with chloroform. Workup gave 280 mg of a pale yellow foam, the TLC of which showed it to be a complex mixture of products. This complex mixture was subjected to preparative TLC separation (30% MeOH in $CHCl_3$), and only one product could be obtained in pure crystalline form (ethyl acetate–hexanes), which was identified as 5-(hydroxymethyl)codeine (**11**) from its spectral properties. Its yield was 60 mg (19.3%): mp 180–182 °C; IR ν 3450, 2950, 2860, 1640, 1610, 1450, 1140, 1100, 970, and 870 cm^{-1}; NMR δ 1.6 (br, 1 H, exchangeable with D_2O), 2.05–2.4 (m, 4 H), 2.42 (s, 3 H, N-Me), 2.50–3.02 (m, 4 H, with a broad bump at δ 2.8, which vanishes on D_2O exchange), 3.31 (m, 1 H), 3.82 (s, 3 H, C_3-OMe), 4.12 (q, 2 H, J = 11.5 Hz, C_5-hydroxymethyl), 4.22 (br s, 1 H, C_6-H), 5.11 (complex d, 1 H, J = 9 Hz, C_8-H), 5.71 (complex d, 1 H, J = 9 Hz, C_7-H), 6.12, 6.62 (AB, 2 H, J = 8 Hz, aromatic H). Anal. Calcd for $C_{19}H_{23}NO_4$: C, 69.28; H, 7.04; N, 4.25. Found: C, 69.06; H, 7.24; N, 4.08.

Acknowledgment. We are indebted to Dr. Arthur Jacobson of the Section on Drug Design and Synthesis, LN, NIDDK, NIH, for arranging for screening tests, and to the National Institute on Drug Abuse for generous financial support under Grant No. 5 RO1DA0 2469. We are also greatly indebted to Professor William D. Jones of these laboratories for carrying out the X-ray crystallographic structural determination of 5-methylheroin (**4**) for us.

Registry No. **1**, 118112-52-0; **2**, 118112-53-1; **3**, 118142-13-5; **4**, 118142-14-6; **5**, 118112-54-2; **6**, 118142-15-7; **8**, 118112-55-3; **9**, 118112-56-4; **10**, 118112-57-5; **11**, 118112-58-6; 5-lithiothebaine, 80583-33-1; 5-methyldihydrocodeine, 118112-59-7; 5-methyldihydroisocodeine, 118112-60-0; 6-*O*-acetyl-5-methylcodeine, 118112-61-1; 6α-*O*-acetyl-5-methyldihydrocodeine, 118112-62-2; 6β-*O*-acetyl-5-methyldihydrocodeine, 118112-63-3.

New Synthesis of Cyclobutane Annelated Compounds by the Use of a (1-Cyclobutenyl)triphenylphosphonium Salt

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Received July 25, 1988

Many methods for the synthesis of cyclobutane fused compounds by means of both photochemical[1] and thermochemical cycloaddition reactions[2] have been well-studied. We have recently reported a new synthesis of heterocyclic fused cyclobutanes by the use of the (1-cyclobutenyl)triphenylphosphonium salt **1**.[3] On the other hand,

(1) For examples, see: (a) Challand, B. D.; Hikino, H.; Kornis, G.; Lange, G.; de Mayo, P. *J. Org. Chem.* **1969**, *34*, 794. (b) Salomon, R. G.; Coughlin, D. J.; Ghosh, S.; Zagorski, M. G. *J. Am. Chem. Soc.* **1982**, *104*, 998. (c) Ghosh, S.; Raychaudhuri, S. R.; Salomon, R. G. *J. Org. Chem.* **1987**, *52*, 83. For some reviews on the photochemical [2 + 2] cycloaddition, see: (d) Dilling, W. L. *Chem. Rev.* **1966**, *66*, 373. (e) Woodward, R. B.; Hoffmann, R. *The Conservation of Orbital Symmetry*; Verlag Chemie: Weinheim, Germany, 1970; p 73. (f) Baldwin, S. W. *Org. Photochem.* **1981**, *5*, 123.

(2) For examples, see: (a) Allinger, N. L.; Nakazaki, M.; Zalkow, V. *J. Am. Chem. Soc.* **1959**, *81*, 4047. (b) Braendlin, H. P.; Grindahl, G. A.; Kim, Y. S.; McBee, E. T. *J. Am. Chem. Soc.* **1962**, *84*, 2112. (c) Hillard, R. L., III; Vollhardt, K. P. C. *J. Am. Chem. Soc.* **1977**, *99*, 4058. (d) Wenkert, E.; Berges, D. A.; Golob, N. F. *J. Am. Chem. Soc.* **1978**, *100*, 1263. (e) Davalian, D.; Garrett, P. J.; Koller, W.; Mansuri, M. M. *J. Org. Chem.* **1980**, *45*, 4183. (f) Negishi, E.; Holmes, S. J.; Tour, J. M.; Miller, J. A. *J. Am. Chem. Soc.* **1985**, *107*, 2568. For some reviews on the thermochemical cycloaddition, see: (g) Bloomfield, J. J.; Owsley, D. C.; Nelke, J. M. *Org. React. (N.Y.)* **1976**, *23*, 259. (h) Vollhardt, K. P. C. *Acc. Chem. Res.* **1977**, *10*, 1. (i) Brady, W. T. *Tetrahedron* **1981**, *37*, 2949.

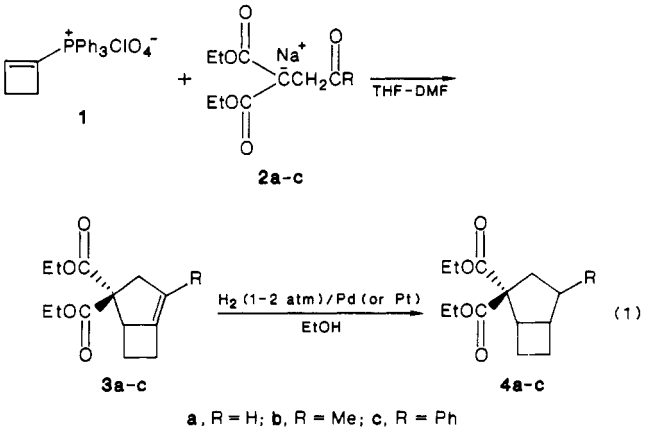
(3) (a) Minami, T.; Sako, H.; Ikehira, T.; Hanamoto, T.; Hirao, I. *J. Org. Chem.* **1983**, *48*, 2569. (b) Minami, T.; Hanamoto, T.; Hirao, I. *J. Org. Chem.* **1985**, *50*, 1278.

(4) Schweizer, E. E.; O'Neill, G. J. *J. Org. Chem.* **1965**, *30*, 2082.

0022-3263/89/1954-0974$01.50/0

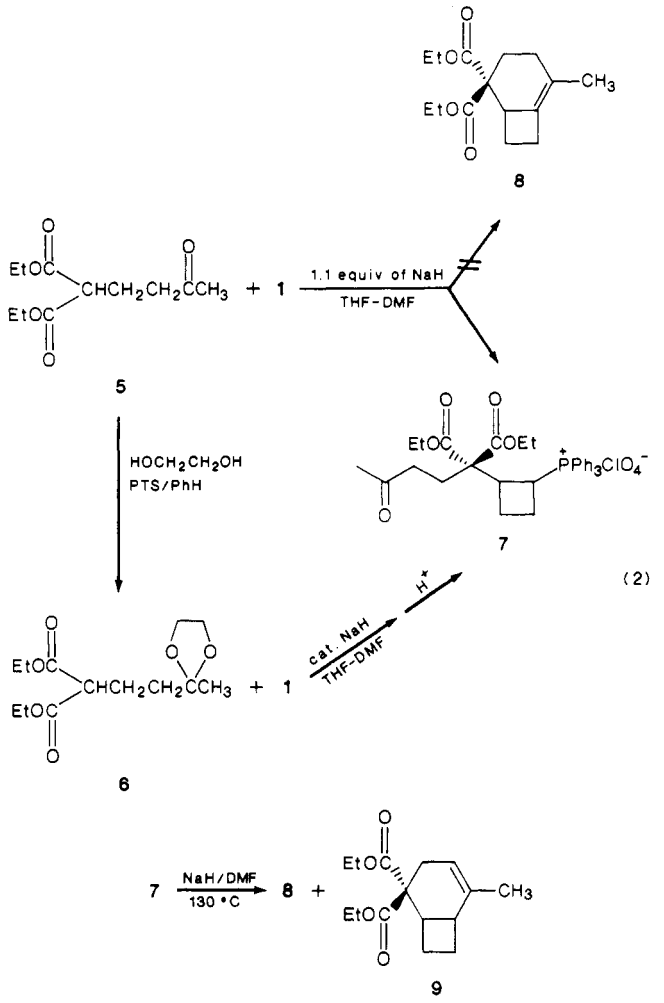
the synthesis of monocyclic alkenes by the reaction of vinyltriphenylphosphonium bromide with (oxoalkyl)-malonates has been reported by Schweizer and O'Neill.[4] We are now able to report the successful application of this methodology to the salt **1** for synthesis of cyclobutane fused carbocyclic compounds.

The Michael addition of carbanions **2a–c**, generated from diethyl (formylmethyl)-, (2-oxopropyl)-, and (benzoylmethyl)malonates and sodium hydride in THF–DMF (5:1) mixtures, to the salt **1** and subsequent intramolecular Wittig reaction gave the desired 4,4-bis(ethoxycarbonyl)-bicyclo[3.2.0]hept-1-enes **3a–c** in 48–86% yields (eq 1). Low-pressure hydrogenation of **3a–c** in ethanol over a palladium (or platinum) catalyst produced the *cis*-bicyclo[3.2.0]heptanes **4a–c** in 59–74% yields, as single stereoisomers.[5]

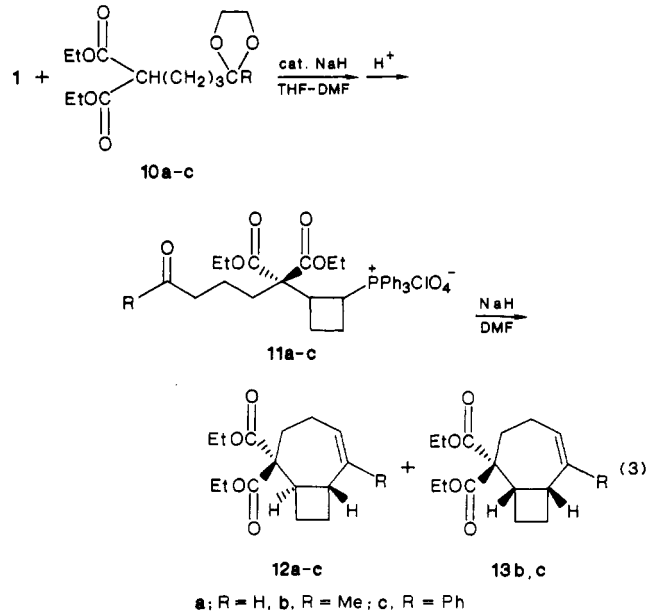


In contrast, the reaction of diethyl (3-oxobutyl)malonate (**5**) with **1** under similar conditions did not lead to the corresponding bicyclo[4.2.0]oct-1-ene **8**, but rather the Michael adduct **7** was obtained in 62% yield. The yield of **7** was improved by reaction of the ethylene ketal of **5** with **1** in the presence of a catalytic amount of NaH, followed by acid-catalyzed hydrolysis to give **7** in quantitative yield. Treatment of this salt **7** with NaH under rather vigorous conditions (DMF, 130 °C, 6 h) led to a 1:1 mixture of the expected **8** and its isomer **9**, albeit in low yield (16%) (eq 2). The structures of **8** and **9** were assigned on the basis of their ^{1}H NMR and ^{13}C NMR spectral data (Table I, supplementary material). That is, the ^{1}H NMR spectrum of **8** shows a signal for methyl (t, J = 7.03 Hz, 6 H) at δ 1.23, the other methyl signal (s, 3 H) at δ 1.50, methylene and methine signals (m, 9 H) at δ 1.67–3.00, and a signal for methylene protons (q, J = 7.03 Hz, 4 H) at δ 4.17, while that of **9** exhibits the corresponding peaks at δ 1.26 (t, J = 7.32 Hz, 6 H, Me), 1.63 (s, 3 H, Me), 1.04–2.48 (m, 8 H, CH_2 and CH), and 4.19 (q, J = 7.32 Hz, 4 H, OCH_2) and one olefinic proton signal (br, 1 H) at δ 5.34.

In a further investigation of the influence of increasing methylene number of the alkyl chain in ketoalkyl-substituted malonic acid esters on the Wittig cyclization reaction, the Michael adducts **11a–c** of (4-oxoalkyl)malonic acid esters to **1**, on similar treatment with NaH in DMF (130 °C, 4 h), did not give the homologous bridgehead olefins, but rather *trans*- and/or *cis*-bicyclo[5.2.0]non-2-enes, **12a–c** and/or **13b,c**, respectively, were produced in

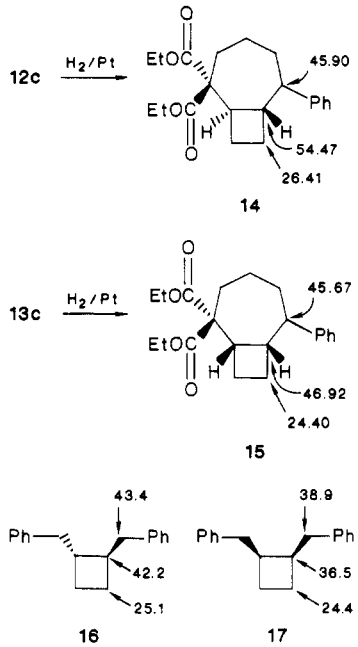


21–33% yields (eq 3). Structural assignments of **12a–c** and **13b,c** were similarly made on the basis of their spectral data (Table I and Experimental Section). For further confirmation of the stereochemistry of the products **12** and **13**, each hydrogenation of **12c** and **13c** was carried out leading to two stereoisomers **14** and **15**, respectively. In order to differentiate the stereochemistry of the hydrogenated products **14** and **15**,[5] the ^{13}C NMR data of **14** and



(5) Although the relative stereochemistry of the methyl and phenyl groups in the hydrogenation products **4b,c**, **14**, and **15** could not be determined on the basis of their ^{1}H and ^{13}C NMR data, we favor that the substituents are located in the endo position on mechanistic grounds.

15 were compared with those of model compounds 16 and 17, which we have previously reported.[6] The carbon



resonances of the cyclobutane ring methylenes and the side-chain methylene in the trans isomer 16 were observed at relatively lower fields than those in the cis isomer 17. On the basis of these observations, we have assigned the compound 14 as the trans structure.

Thus, synthesis of cyclobutane annelated compounds was achieved via one-pot Wittig reaction or intramolecular Wittig condensation of preformed carbonyl phosphonium salts, although the product yields are not necessarily satisfactory.

Experimental Section

General. ^1H NMR and ^{13}C NMR spectra were obtained on a JEOL JNM-FX-60 instrument in $CDCl_3$ operating at 60 and 15.04 MHz with Me_4Si as an internal standard. IR spectra were recorded with a Shimadzu IR-408 instrument. Mass spectra were taken with JEOL DX-300 spectrometer. Melting points were measured in open capillary tubes and are uncorrected.

^{13}C NMR spectra data of the products **3a–c**, **4a–c**, **8**, **9**, **12a–c**, **13b,c**, **14**, and **15** are summarized in Table I.

General Procedure for the Synthesis of 3a–c. To a solution of the carbanion **2a**, **2b**, or **2c**, generated from diethyl (formylmethyl)-, (2-oxopropyl)-, or (benzoylmethyl)malonate (1.2 mmol) with NaH (60% in oil, 44 mg, 1.1 mmol) in dry THF–DMF (6 mL, 5:1) at room temperature, was added (1-cyclobutenyl)triphenylphosphonium perchlorate (**1**) (415 mg, 1.0 mmol) with stirring. The mixture was stirred overnight at room temperature and then refluxed for 1 h. After the reaction mixture was neutralized with an aqueous NH_4Cl solution, the mixture was extracted with CH_2Cl_2, washed with H_2O, dried over Na_2SO_4, and evaporated. Column chromatography of the residue on silica gel with benzene gave samples **3a–c**. The products had the following properties.

4,4-Bis(ethoxycarbonyl)bicyclo[3.2.0]hept-1-ene (3a): yield 115 mg, 48%; IR (neat) 2900, 1725, 1665 cm^{-1}; ^1H NMR δ 1.23 (t, J = 7.14 Hz, 6 H, CH_3), 1.50–3.25 (m, 6 H, CH_2), 3.65–4.40 (br m, 1 H, CH), 4.19 (q, J = 7.14 Hz, 4 H, OCH_2), 5.16 (br s, 1 H, olefinic H); HRMS m/z calcd for $C_{13}H_{18}O_4$ 238.1205, found 238.1212.

4,4-Bis(ethoxycarbonyl)-2-methylbicyclo[3.2.0]hept-1-ene (3b): yield 200 mg, 79%; IR (neat) 2950, 1730 cm^{-1}; ^1H NMR δ 1.23 (t, J = 7.18 Hz, 6 H, CH_3), 1.64 (s, 3 H, CH_3), 2.10–3.00 (m, 6 H, CH_2), 3.70–4.40 (br m, 1 H, CH), 4.17 (q, J = 7.18 Hz, 4 H, OCH_2); EIMS, m/z 253 (M^+ + 1).[7]

4,4-Bis(ethoxycarbonyl)-2-phenylbicyclo[3.2.0]hept-1-ene (3c): yield 270 mg, 86%; IR (neat) 2950, 1725, 1655, 1595 cm^{-1}; ^1H NMR δ 1.20 (t, J = 7.18 Hz, 3 H, CH_3), 1.24 (t, J = 7.18 Hz, 3 H, CH_3), 1.40–3.72 (m, 6 H, CH_2), 3.72–4.40 (m, 5 H, CH and OCH_2), 7.00–7.50 (m, 5 H, phenyl H); EIMS, m/z 285 (M^+ – C_2H_5).[7]

Hydrogenation of 3a–c. Hydrogenation of **3a–c** (0.50 mmol) in ethanol (20 mL) over PtO_2 (10 mg) or Pd/C (100 mg) at 1–2 atm of hydrogen pressure for 7 h afforded **4a–c**.

2,2-Bis(ethoxycarbonyl)bicyclo[3.2.0]heptane (4a): yield 72 mg, 60%; IR (neat) 2930, 1725 cm^{-1}; ^1H NMR δ 1.22 (t, J = 6.96 Hz, 6 H, CH_3), 1.37–3.50 (m, 10 H, CH_2 and CH), 4.15 (q, J = 6.96 Hz, 4 H, OCH_2); EIMS, m/z 167 (M^+ – EtOCO).[7]

2,2-Bis(ethoxycarbonyl)-4-methylbicyclo[3.2.0]heptane (4b): yield 94 mg, 74%; IR (neat) 2950, 1725 cm^{-1}; ^1H NMR δ 0.93 (d, J = 6.01 Hz, 3 H, CH_3), 1.21 (t, J = 7.03 Hz, 3 H, CH_3), 1.23 (t, J = 7.03 Hz, 3 H, CH_3), 1.40–3.56 (m, 9 H, CH_2 and CH), 4.15 (q, J = 7.03 Hz, 4 H, OCH_2); CIMS (isobutane), m/z 255 (M^+ + 1).

2,2-Bis(ethoxycarbonyl)-4-phenylbicyclo[3.2.0]heptane (4c): yield 93 mg, 59%; IR (neat) 2950, 1725, 1600, 750, 700 cm^{-1}; ^1H NMR δ 1.24 (t, J = 7.03 Hz, 6 H, CH_3), 1.28–3.70 (m, 9 H, CH_2 and CH), 4.19 (q, J = 7.03 Hz, 4 H, OCH_2), 7.22 (s, 5 H, phenyl H); HRMS m/z calcd for $C_{19}H_{24}O_4$ 316.1674, found 316.1655.

Preparation of [2-[1′,1′-Bis(ethoxycarbonyl)-4′-oxopentyl]cyclobutyl]triphenylphosphonium Perchlorate (7). To a solution of diethyl (3-oxobutyl)malonate ethylene ketal (**6**) (4.72 g, 17.2 mmol) in dry THF–DMF (90 mL, 5:1) at room temperature were added NaH (60% in oil, 125 mg, 3.1 mmol) and the salt **1** (6.15 g, 15.7 mmol) with stirring. After being stirred overnight at room temperature, the reaction mixture was heated with 12% hydroperchloric acid (20 mL) at reflux for 1 h. The reaction mixture was extracted with CH_2Cl_2, washed with H_2O, dried (Na_2SO_4), and concentrated. The residue was dissolved in CH_2Cl_2 and precipitated with Et_2O. The collected solid was vacuum-dried to afford 10.12 g (100% yield) of the salt **7**.

7: mp 139–143 °C; IR (KBr) 2950, 1715, 1425, 1090, 750, 720, 690 cm^{-1}; ^1H NMR δ 1.11 (t, J = 7.18 Hz, 3 H, CH_3), 1.41 (t, J = 7.03 Hz, 3 H, CH_3), 2.06 (s, 3 H, CH_3), 1.56–3.20 (m, 9 H, CH_2 and CH), 3.67 (q, J = 7.18 Hz, 2 H, OCH_2), 4.50 (q, J = 7.03 Hz, 2 H, OCH_2), 4.20–4.90 (br m, 1 H, CH), 7.30–8.10 (m, 15 H, phenyl H).

General Procedure for the Synthesis of 8 and 9. To a solution of the salt **7** (645 mg, 1.0 mmol) in dry DMF (20 mL) was added NaH (60% in oil, 44 mg, 1.1 mmol). The solution was heated at 130 °C for 6 h with stirring. After the reaction mixture was neutralized with 2 N HCl, the mixture was extracted with CH_2Cl_2. After similar workup, the residue was chromatographed on preparative TLC (silica gel, Wakogel B-5F, benzene) to give **8** (22 mg, 8%) and **9** (22 mg, 8%). The products had the following properties.

5,5-Bis(ethoxycarbonyl)-2-methylbicyclo[4.2.0]oct-1-ene (8): IR (neat) 2880, 1720 cm^{-1}; HRMS m/z calcd for $C_{15}H_{22}O_4$ 266.1518, found 266.1498.

5,5-Bis(ethoxycarbonyl)-2-methylbicyclo[4.2.0]oct-2-ene (9): IR (neat) 2880, 1725 cm^{-1}; HRMS m/z calcd for $C_{15}H_{22}O_4$ 266.1518, found 266.1544.

Preparation of the Michael Adducts 11a–c. To a solution of diethyl (formylpropyl)-, (4-oxopentyl)-, and (benzoylpropyl)malonate ethylene ketals (**10a–c**) (11 mmol) in dry THF–DMF (36 mL, 5:1) at room temperature were added NaH (60% in oil, 1.0 mmol) and the salt **1** (4.15 g, 10 mmol) with stirring. After being stirred overnight at room temperature, the reaction mixture was heated with 12% hydroperchloric acid (10 mL) at refluxing temperature for 1 h. After similar workup, the residue was dissolved in CH_2Cl_2 and precipitated with Et_2O. After the collected solids were vacuum-dried, the salts **11a** (4.19 g, 65%), **11b**

(6) Minami, T.; Harui, N.; Taniguchi, Y. *J. Org. Chem.* **1986**, *51*, 3572.

(7) Mass spectra of compounds **3b,c** and **4a** did not show parent ion peaks, but spectral assignments of **3b,c** and **4a** were clearly made as the structures **3b,c** and **4a** on the basis of their spectral data.

(6.19 g, 94%), and **11c** (6.05 g, 84%) were obtained.

[2-[1',1'-Bis(ethoxycarbonyl)-5'-oxopentyl]cyclobutyl]triphenylphosphonium perchlorate (11a): mp 165–169 °C; IR (KBr) 2950, 1720, 1585, 1485, 1435, 1100–1060, 745, 720, 690 cm^{-1}; ^1H NMR δ 1.12 (t, J = 6.96 Hz, 3 H, CH_3), 1.41 (t, J = 7.14 Hz, 3 H, CH_3), 1.50–3.25 (m, 11 H, CH_2 and CH), 3.72 (q, J = 7.14 Hz, 2 H, OCH_2), 4.47 (q, J = 6.96 Hz, 2 H, OCH_2), 4.16–5.00 (br, 1 H, CH), 7.30–8.25 (m, 15 H, phenyl H), 9.68 (s, 1 H, CHO).

[2-[1',1'-Bis(ethoxycarbonyl)-5'-oxohexyl]cyclobutyl]triphenylphosphonium perchlorate (11b): mp 149–152 °C; IR (KBr) 2950, 2900, 1740, 1720, 1585, 1485, 1440, 1100–1070, 750, 720, 690 cm^{-1}; ^1H NMR δ 1.12 (t, J = 7.18 Hz, 3 H, CH_3), 1.41 (t, J = 7.18 Hz, 3 H, CH_3), 1.50–3.30 (m, 11 H, CH_2 and CH), 2.09 (s, 3 H, CH_3), 3.73 (q, J = 7.18 Hz, 2 H, OCH_2), 4.49 (q, J = 7.18 Hz, 2 H, OCH_2), 4.20–5.00 (br, 1 H, CH), 7.36–8.10 (m, 15 H, phenyl H).

[2-[1',1'-Bis(ethoxycarbonyl)-4'-benzoylbutyl]cyclobutyl]triphenylphosphonium perchlorate (11c): mp 138–143 °C; IR (KBr) 2950, 2900, 1740, 1720, 1680, 1590, 1485, 1440, 1110–1070, 755, 720, 690 cm^{-1}; ^1H NMR δ 1.02 (t, J = 6.96 Hz, 3 H, CH_3), 1.38 (t, J = 6.96 Hz, 3 H, CH_3), 1.50–3.25 (m, 11 H, CH_2 and CH), 3.72 (q, J = 6.96 Hz, 2 H, OCH_2), 4.50 (q, J = 6.96 Hz, 2 H, OCH_2), 4.10–5.00 (br 1 H, CH), 7.20–8.25 (m, 20 H, phenyl H).

General Procedure for the Synthesis of 12a–c and/or 13b,c. To a solution of the salt **11a–c** (1.0 mmol) in dry DMF (10 mL) was added NaH (60% in oil, 44 mg, 1.1 mmol). The solution was heated at 130 °C for 4 h with stirring. After similar workup, the residue was chromatographed on preparative TLC (silica gel, Wakogel B-5F, benzene) to give samples **12a–c** and/or **13b,c**.

6,6-Bis(ethoxycarbonyl)-*trans*-bicyclo[5.2.0]non-2-ene (12a): yield 56 mg, 21%; IR (neat) 2950, 1720 cm^{-1}; ^1H NMR δ 1.24 (t, J = 7.03 Hz, 3 H, CH_3), 1.26 (t, J = 7.03 Hz, 3 H, CH_3), 1.00–3.00 (m, 10 H, CH_2 and CH), 3.90–4.50 (m, 4 H, OCH_2), 5.60–5.92 (m, 2 H, olefinic H); HRMS m/z calcd for $C_{15}H_{22}O_4$ 266.1518, found 266.1508.

6,6-Bis(ethoxycarbonyl)-2-methyl-*trans*-bicyclo[5.2.0]non-2-ene (12b): yield 60 mg, 11%; IR (neat) 2950, 1720 cm^{-1}; ^1H NMR δ 1.25 (t, J = 7.03 Hz, 6 H, CH_3), 1.74 (d, J = 1.32 Hz, 3 H, CH_3), 1.50–3.00 (m, 10 H, CH_2 and CH), 4.14 (q, J = 7.03 Hz, 4 H, OCH_2), 5.42 (br, 1 H, olefinic H); HRMS m/z calcd for $C_{16}H_{24}O_4$ 280.1675, found 280.1688.

6,6-Bis(ethoxycarbonyl)-2-methyl-*cis*-bicyclo[5.2.0]non-2-ene (13b): yield 93 mg, 17%; IR (neat) 2880, 1720 cm^{-1}; ^1H NMR δ 1.25 (t, J = 7.03 Hz, 6 H, CH_3), 1.62 (d, J = 1.47 Hz, 3 H, CH_3), 1.44–2.80 (m, 10 H, CH_2 and CH), 4.14 (q, J = 7.03 Hz, 4 H, OCH_2), 5.59 (br, 1 H, olefinic H); HRMS m/z calcd for $C_{16}H_{24}O_4$ 280.1675, found 280.1661.

6,6-Bis(ethoxycarbonyl)-2-phenyl-*trans*-bicyclo[5.2.0]non-2-ene (12c): yield 39 mg, 11%; IR (neat) 2900, 1720, 1595, 760, 695 cm^{-1}; ^1H NMR δ 1.22 (t, J = 7.03 Hz, 3 H, CH_3), 1.26 (t, J = 7.03 Hz, 3 H, CH_3), 1.44–2.90 (m, 10 H, CH_2 and CH), 4.15 (q, J = 7.03 Hz, 2 H, OCH_2), 4.18 (q, J = 7.03 Hz, 2 H, OCH_2), 6.07 (t, J = 3.66 Hz, 1 H, olefinic H), 6.90–7.38 (m, 5 H, phenyl H); HRMS m/z calcd for $C_{21}H_{26}O_4$ 342.1831, found 342.1794.

6,6-Bis(ethoxycarbonyl)-2-phenyl-*cis*-bicyclo[5.2.0]non-2-ene (13c): yield 77 mg, 22%; IR (neat) 2900, 1715, 1590, 750, 695 cm^{-1}; ^1H NMR δ 1.08 (t, J = 7.03 Hz, 3 H, CH_3), 1.19 (t, J = 6.89 Hz, 3 H, CH_3), 1.48–2.96 (m, 10 H, CH_2 and CH), 4.07 (q, J = 7.03 Hz, 2 H, OCH_2), 4.15 (q, J = 6.98 Hz, 2 H, OCH_2), 5.85 (t, J = 3.66 Hz, 1 H, olefinic H), 6.80–7.30 (m, 5 H, phenyl H); HRMS m/z calcd for $C_{21}H_{26}O_4$ 342.1831, found 342.1829.

Hydrogenation of 12c and 13c. Hydrogenation of **12c** (48 mg, 0.14 mmol) and **13c** (90 mg, 0.26 mmol) in ethanol (20 mL) over PtO_2 (10 mg) at 1–2 atm of hydrogen pressure for 7 h afforded **14** (30 mg, 62%) and **15** (51 mg, 56%), respectively.

2,2-Bis(ethoxycarbonyl)-6-phenyl-*trans*-bicyclo[5.2.0]nonane (14): IR (neat) 2900, 2830, 1715, 1595, 745, 695 cm^{-1}; ^1H NMR δ 1.07 (t, J = 7.03 Hz, 3 H, CH_3), 1.27 (t, J = 7.03 Hz, 3 H, CH_3), 1.00–3.00 (m, 13 H, CH_2 and CH), 3.68–4.40 (m, 4 H, OCH_2), 6.80–7.40 (m, 5 H, phenyl H); HRMS m/z calcd for $C_{21}H_{28}O_4$ 344.1987, found 344.2007.

2,2-Bis(ethoxycarbonyl)-6-phenyl-*cis*-bicyclo[5.2.0]nonane (15): IR (neat) 2900, 2830, 1715, 1595, 750, 695 cm^{-1}; ^1H NMR δ 1.14 (t, J = 7.03 Hz, 3 H, CH_3), 1.37 (t, J = 7.03 Hz, 3 H, CH_3), 1.00–3.00 (m, 13 H, CH_2 and CH), 3.80–4.52 (m, 4 H, OCH_2), 7.00–7.58 (m, 5 H, phenyl H); HRMS m/z calcd for $C_{21}H_{28}O_4$ 344.1987, found 344.2015.

Acknowledgment. We are grateful for financial support of this work by a Grant-in-Aid for Scientific Research on Priority Areas from the Japan Ministry of Education, Science and Culture.

Registry No. 1, 86046-73-3; **3a**, 118418-37-4; **3b**, 118418-46-5; **3c**, 118418-47-6; **4a**, 118418-38-5; **4b**, 118418-48-7; **4c**, 118418-49-8; **5**, 4761-26-6; **6**, 7796-23-8; **7**, 118418-40-9; **8**, 118418-41-0; **9**, 118418-42-1; **10a**, 118418-43-2; **10b**, 101417-29-2; **10c**, 118418-58-9; **11a**, 118457-88-8; **11b**, 118418-51-2; **11c**, 118418-53-4; **12a**, 118418-44-3; **12b**, 118418-54-5; **12c**, 118418-55-6; **13b**, 118418-56-7; **13c**, 118418-57-8; **14**, 118418-45-4; **15**, 118490-60-1; diethyl (formylmethyl)malonate, 23193-16-0; diethyl (2-oxopropyl)malonate, 23193-18-2; diethyl (benzoylmethyl)malonate, 94011-49-1.

Supplementary Material Available: Table I giving ^{13}C NMR data of compounds **3a–c**, **4a–c**, **8**, **9**, **12a–c**, **13b,c**, **14**, and **15** (2 pages). Ordering information is given on any current masthead page.

Palladium(0)-Catalyzed Reaction of Methyl γ,δ-Epoxysorbate with Nitrogen Nucleophiles

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Received August 30, 1988

The reaction of nucleophiles and (π-allyl)palladium complexes bearing functional groups is useful for the synthesis of complex organic molecules.[1] Many regioselective nucleophilic reactions toward (π-allyl)palladium complexes having one functional group at an allylic carbon atom have been reported.[1,2] On the other hand, examples of the reaction involving (π-allyl)palladium complexes having two different functional groups at both allylic carbon atoms are limited. A hydroxyalkyl[3] or alkoxycarbonyl[4] functional group is known to direct carbon or nitrogen nucleophiles to attack regioselectively the allylic carbon atom distal to the functional group. As to competition of these two functional groups in the control of regioselectivity, the palladium(0)-catalyzed reaction of methyl γ,δ-epoxysorbate (**1**) with carbon nucleophiles has recently been reported.[3b,c] In this reaction, the directing effect of the hydroxyalkyl group generated from the oxirane ring dominates over that of the alkoxycarbonyl group: carbon–carbon bond formation takes place regioselectively

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(4) For the carbon nucleophile, see: (a) Jackson, W. R.; Strauss, J. U. G. *Tetrahedron Lett.* **1975**, 2591 and ref 2b. For the nitrogen nucleophile, see: (b) Tanikaga, R.; Takeuchi, J.; Takyu, M.; Kaji, A. *J. Chem. Soc., Chem. Commun.* **1987**, 386.

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