fraction [118–120° (0.025 mm)] was chiefly (85% pure) **8** (15% yield). Further purification of **7** and **8** was effected by distillation at 55 (0.005 mm) and 116° (0.005 mm), respectively.

For **7**: λ_{max} (CCl_4) 3.19, 3.29, 5.83, 5.93, and 6.12 μ; nmr (CCl_4) τ 4.24 (d, J = 10.5 Hz, of t, J = 2 Hz, 1 H), 7.25–9.3 ppm (m, 13 H); *m/e* 150 (parent), 122 (base peak).

For **8**: λ_{max} (CCl_4) 5.70 sh, 5.7, 9.41 sh, 9.67 μ; nmr (CCl_4) τ 5.88 (q, J = 7 Hz, 4 H), 6.3 (d, J = 7 Hz, 1 H), 6.8 (m, 1 H), 7.1–9.9 ppm (m, 20 H, containing t, J = 7 Hz, at 8.77 ppm); *m/e* 310 (parent), 264 (base peak).

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Registry No.—**3**, 39000-53-8; **4**, 51933-04-1; **7**, 51933-05-2; **8**, 51933-06-3; diethyl malonate, 105-53-3; cyclopropanecarboxaldehydes, 1489-69-6; *n*-butyl mercaptan, 109-79-5; 1-pyrrolidinocyclohexene, 1125-99-1.

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Preparation and Reactions of a Tris Annelating Agent

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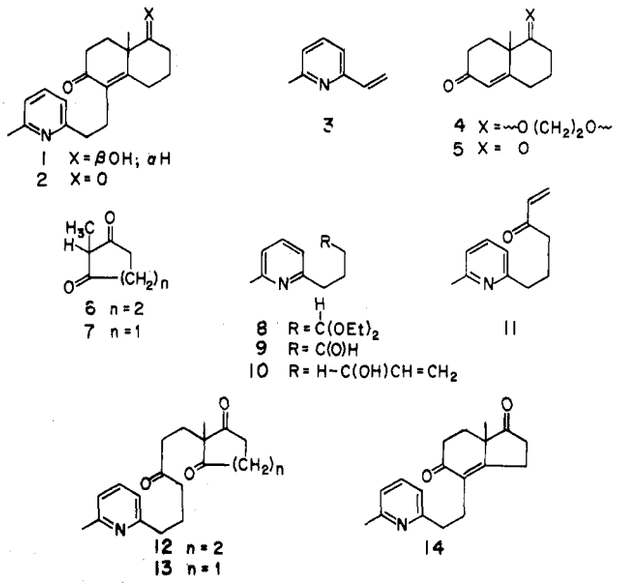
Recently we reported the synthesis of *dl*-D-homoestrone *via* the picolylethylated octalone derivative **1**.[1] This intermediate was assembled by the Michael reaction of ketalenone **4** with bis annelating agent[2] **3**. Precursor **4** is the monoketalization product[3,4] of the Wieland–Miescher ketone **5**, itself the Robinson annelation product of diketone **6** with methyl vinyl ketone.[5,6] The vinylpicoline **3**[7] is obtained in low yield[7] *via* hydroxymethylation of 2,6-lutidine.

A major simplification in the lutidine route to 19-norsteroids could be contemplated by the utilization of the tris annelating agent **11**. Were this compound to be easily available, its merger with diketones (*e.g.*, **6**) to produce, directly, products such as **2** could be envisioned as a means of eliminating the lowest yield facets of the synthetic approach described above. Below we set forth a convenient and efficient synthesis of **11**. Its high-yield condensations with **6** and **7** are also described.

Treatment of 2,6-lutidine with phenyllithium followed by alkylation of the resultant anion with 3-chloropropionaldehyde diethyl acetal[8] gives **8**, which is converted, without purification, to aldehyde **9** (70% overall). Addition of



vinylmagnesium chloride to **9** gives (89%) alcohol **10** which undergoes oxidation by manganese dioxide to afford (88%) the desired **11**.

Some indication of the potential applications of this compound can be seen from the following experiments. Under the influence of sodium hydride, enone **11** couples smoothly with **6** to give **12**. Cyclization of **12** under the influence of 3-aminopropionic acid[9] affords (75%) **2**, which is converted to its crystalline dihydro derivative **1**.

Condensation of **7** with **11** can be conducted in one step in aqueous acid to give enedione **14** in 92% yield. Alternatively **7** and **11** can be coupled through the action of triethylamine in ethyl acetate[10] to give trione **13**, which can be cyclized, in a separate step, *via* 3-aminopropionic acid[9] to give **14**.

The advantages[9] of passing through symmetrical intermediates such as **12** and **13** on the way to compounds such as **2** and **14** will be set forth in future publications.

Experimental Section[11]

Preparation of Picolylbutyraldehyde 9. To a stirred solution containing 16.2 g (0.15 mol) of 2,6-lutidine in 250 ml of dry THF (freshly distilled from CaH_2) under a nitrogen atmosphere was slowly added 65 ml (0.15 mol) of 2.4 *M* PhLi in 70:30 benzene–ether. The resulting solution was stirred at room temperature for 20 min. After cooling to 0°, 10.6 g (0.10 mol) of 3-chloropropionaldehyde diethyl acetal was slowly added. After stirring for 30 min at 0°, the solution was refluxed for 12 hr. The solution was then cooled to room temperature, 150 ml of aqueous 10% HCl was slowly added, and the resulting solution was stirred for 5 hr. The solution was then neutralized with $NaHCO_3$ and extracted with 5 × 100 ml CH_2Cl_2, and the combined organic extracts were dried over anhydrous Na_2SO_4. After evaporation of the solvents, distillation afforded 10.84 g (70%) of **9** as an oil: bp 64–65° (0.05 mm); ir ($CHCl_3$) 2810, 2710, 1715, 1590, 1575 cm^{-1}; nmr (CCl_4) δ 1.8–2.4 (m, 4 H), 2.48 (s, 3 H), 2.68 (t, 2 H), 6.90 (d, 2 H), 7.38 (t, 1 H); *m/e* 163.

Although this material was judged to be pure by nmr, two combustion analyses[11] gave results not in accord with prediction.

Preparation of Allylic Alcohol 10. To a stirred solution containing 8.2 g (0.05 mol) of aldehyde **9** in 150 ml of dry THF (freshly distilled from CaH_2) under a nitrogen atmosphere and at −78° was slowly added 26.4 ml (0.075 mol) of 2.84 *M* vinylmagnesium chloride in THF. The resulting solution was stirred for 0.5 hr at −78° and then at room temperature for 1.5 hr. The solution was then poured into 50 ml of H_2O and acidified with 10% HCl. After neutralization with $NaHCO_3$, the organic layer was separated and the aqueous layer was extracted with 4 × 50 ml of CH_2Cl_2. Evaporation of the solvent and filtration of the residue through 150 g of silica gel using 3:1 hexane–ethyl acetate as the eluent afforded 8.5 g (89%) of the desired allylic alcohol **10** as a pale yellow oil: ir

($CHCl_3$) 3600, 3450, 1590, 1575, 990, 925 cm^{-1}; nmr ($CDCl_3$) δ 1.5–2.1 (m, 4 H), 2.59 (s, 3 H), 2.80 (t, 2 H), 4.18 (q, 1 H), 4.39 (s, 1 H), 4.9–5.4 (m, 2 H), 5.65–6.2 (m, 1 H), 6.90 (d, 2 H), 7.38 (t, 1 H); *m/e* 191.

Anal. Calcd for $C_{12}H_{17}NO$: C, 75.35; H, 8.96; N, 7.32. Found: C, 74.95; H, 8.66; N, 7.21.

Preparation of Pyridine Enone 11. A solution containing 12.0 g (0.063 mol) of allylic alcohol **10** and 120 g of activated MnO_2[12] in 300 ml of CH_2Cl_2 was refluxed for 5 hr. The mixture was filtered, the precipitate was thoroughly washed with $CHCl_3$, and the combined washings were concentrated. Filtration of the concentrate through 200 g of silica gel using 3:1 hexane–ethyl acetate as the eluent afforded 10.5 g (88%) of the desired vinyl ketone **11** as a pale yellow oil: ir ($CHCl_3$) 1670, 1610, 1590, 1575 cm^{-1}; nmr ($CDCl_3$) δ 1.97 (m, 2 H), 2.47 (s, 3 H), 2.55–3.0 (m, 4 H), 5.66 (d of d, 1 H), 6.21 (m, 2 H), 6.90 (d, 2 H), 7.38 (m, 1 H); *m/e* 189.

Anal. Calcd for $C_{12}H_{15}NO$: C, 76.16; H, 7.99; N, 4.65. Found: C, 76.15; H, 7.65; N, 4.50.

Coupling of Diketone 6 with Vinyl Ketone 11. Formation of Adduct 12. To a solution containing 1.5 g (0.0118 mol) of 2-methyl-1,3-cyclohexanedione in 50 ml of dry DME (freshly distilled from CaH_2) under a nitrogen atmosphere was added 10 mg of NaH. After stirring for 10 min at room temperature, 2.0 g (0.0106 mol) of vinyl ketone **11** in 10 ml of dry DME was slowly added. The resulting solution was heated under reflux for 0.5 hr and cooled to room temperature, and 25 ml of H_2O was added. The mixture was extracted with 3 × 25 ml of CH_2Cl_2 and the combined organic extracts were dried over anhydrous Na_2SO_4. After removal of the solvents, the residue was chromatographed on 100 g of silica gel. Elution with $CHCl_3$ afforded 3.18 g (95%) of trione **12** as an oil: ir ($CHCl_3$) 1710, 1690, 1590, 1575 cm^{-1}; nmr ($CDCl_3$) δ 1.27 (s, 3 H), 1.8–2.9 (m, 19 H), 6.90 (d, 2 H), 7.38 (t, 1 H); *m/e* 315.

Anal. Calcd for $C_{19}H_{25}NO_3$: C, 72.35; H, 7.99; N, 4.44. Found: C, 72.50; H, 8.15; N, 4.50.

Cyclodehydration of Trione 12. Formation of Octalindione 2. A solution containing 1.0 g (3.18 mmol) of trione **12**, 565 mg (6.36 mmol) of 3-aminopropionic acid, and 2.5 ml of 1 *N* $HClO_4$ in 25 ml of CH_3CN was heated under reflux for 55 hr. The solution was cooled to room temperature, 25 ml of H_2O was added, and the mixture was neutralized with $NaHCO_3$. This mixture was extracted with 4 × 25 ml of CH_2Cl_2, the combined organic extracts were dried, the solvents were evaporated, and the residue was chromatographed on 50 g of silica gel. Elution with $CHCl_3$ afforded 711 mg (75%) of **2** as an oil: ir ($CHCl_3$) 1705, 1665, 1590, 1575 cm^{-1}; nmr ($CDCl_3$) δ 1.38 (s, 3 H), 1.8–3.0 (m, 17 H), 6.90 (t, 2 H), 7.38 (t, 1 H); *m/e* 297.

Reduction of Picolylethylated Octalindione. Preparation of Hydroxyoctalone 1. To a solution containing 750 mg (2.5 mmol) of enedione **2** in 25 ml of absolute ethanol under an atmosphere of nitrogen at 0° was added 47.5 mg (1.25 mmol) of $NaBH_4$. The solution was stirred at 0° for 0.5 hr and then at room temperature for 1.5 hr. To the resulting solution was then added 10 ml of saturated KCl solution and the mixture was extracted with 4 × 25 ml of $CHCl_3$. The combined organic extracts were dried over anhydrous Na_2SO_4 and, after evaporation of the solvents, the residue was chromatographed on 50 g of silica gel. Elution with $CHCl_3$ afforded 682 mg (91%) of hydroxyenone **1** as white crystals, which were recrystallized from ethyl acetate–hexane: mp 103–104°;[1] ir ($CHCl_3$) 3600, 3400, 1660 1590, 1575 cm^{-1}; nmr ($CDCl_3$) δ 1.07 (s, 3 H), 1.5–2.9 (m, 17 H), 3.24 (t, 1 H), 3.31 (s, 1 H), 6.90 (t, 2 H), 7.38 (t, 1 H); *m/e* 299.

Anal. Calcd for $C_{19}H_{25}NO_2$: C, 76.22; H, 8.42; N, 4.68. Found: C, 76.14, H, 8.37; N, 4.52.

One-Step Condensation of Vinyl Ketone 11 with Diketone 7. Formation of Enedione 14. A solution containing 50 g (0.0264 mol) of vinyl ketone **11** and 3.88 g (0.0345 mol) of 2-methyl-1,3-cyclopentanedione (**7**) in 100 ml of aqueous 10% H_2SO_4 was heated under reflux for 20 hr. The solution was then cooled to room temperature, neutralized with $NaHCO_3$, and extracted with 3 × 25 ml of CH_2Cl_2. The combined organic extracts were dried over anhydrous Na_2SO_4 and, after evaporation of the solvent, the residue was chromatographed on 250 g of silica gel. Elution with $CHCl_3$ afforded 6.9 g (29%) of **14** as a pale yellow oil:[13] ir ($CHCl_3$) 1740, 1660, 1590, 1575 cm^{-1}; nmr ($CDCl_3$) δ 1.12 (s, 3 H), 1.9–3.0 (m, 15 H), 6.92 (t, 2 H), 7.41 (t, 1 H); *m/e* 283.

Anal. Calcd for $C_{18}H_{21}NO_2$: C, 76.30; H, 7.47; N, 4.94. Found: C, 76.21; H, 7.38; N, 4.80.

Coupling of Diketone 7 with Vinyl Ketone 11. Formation of Adduct 13. To a solution containing 5.0 g (0.0264 mol) of vinyl ketone **11** and 3.8 g (0.034 mol) of 2-methyl-1,3-cyclopentanedione in 20 ml of ethyl acetate was added 10 ml of 20% Et_3N in ethyl acetate. After stirring at room temperature for 36 hr the resulting solution was added to 15 ml of H_2O. The mixture was extracted with 3 × 20 ml of $CHCl_3$ and the combined extracts were dried over anhydrous Na_2SO_4. Evaporation of the solvent afforded 7.88 g of crude trione **13**. Examination of the "crude" material by tlc (4:4:1 hexane–ethyl acetate–methanol) showed one spot, R_f 0.43, and the absence of **11**, R_f 0.56. A small spot at the origin appeared to be the only contamination. Trione **13** showed ir ($CHCl_3$) 1785 (shoulder), 1721, 1590, 1575 cm^{-1}; nmr ($CDCl_3$) δ 1.10 (s, 3 H), 1.6–2.2 (m, 4 H), 2.3–2.9 (m, 13 H), 6.90 (d, 2 H), 7.38 (t, 1 H); *m/e* 301.

Preparation of Enedione 14 from Trione 13. A solution containing 7.88 g (0.028 mol) of crude trione **13**, 4.45 g (0.050 mol) of 3-aminopropionic acid, and 10.5 ml of 1 *N* $HClO_4$ in 105 ml of CH_3CN was heated under reflux for 55 hr. The resulting solution was cooled to room temperature, 50 ml of H_2O was added, and the solution was neutralized with $NaHCO_3$. The solution was then extracted with 4 × 50 ml of CH_2Cl_2 and the combined organic extracts were dried over anhydrous Na_2SO_4. Evaporation of the solvents and chromatography on 500 g of silica gel afforded 7.04 g (7) of the enedione **14** after elution with $CHCl_3$.

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Registry No.—**1**, 51965-91-4; **2**, 51965-92-5; **6**, 1193-55-1; **7**, 765-69-5; **9**, 46119-04-4; **10**, 51965-93-6; **11**, 51965-94-7; **12**, 51965-95-8; **13**, 51965-96-9; **14**, 51965-97-0; 2,6-lutidine, 108-48-5; 3-chloropropionaldehyde diethyl acetal, 35573-93-4; 3-aminopropionic acid, 107-95-9.

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Phenylation of Perchlorocyclobutenone

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The interaction of perchlorocyclobutenone (1,2,3,3-tetrachlorocyclobutene-4-one, 1) with benzene under Friedel–Crafts conditions was first studied by De Selms, *et al.*,[1] who observed no phenylation in the presence of 1 molar equiv of aluminum chloride. Subsequently, Ried and Lantzsch,[2] employing 3 molar equiv of the same Lewis acid, obtained the two polyphenylated cyclobutene derivatives, 1,2,3,3-tetraphenylcyclobuten-4-one (**6**) and 3-chloro-1,2,3,4,4-pentaphenylcyclobutene (**8**), in respective yields of 25 and 50%.