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Abstract
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Disciplines
Chemistry | Organic Chemistry | Other Chemistry | Polymer Chemistry

Synthesis of Deoxyfrenolicin and Nanaomycin A

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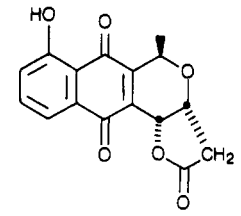
Deoxyfrenolicin and nanaomycin A have been synthesized. Key steps in the synthesis include a phthalide annulation reaction to produce a naphthoquinone, a tandem Diels–Alder/retro-Claisen reaction to produce the carbon skeleton, and a stereoselective reduction of a hemiketal.

The pyranoquinone antibiotics are a diverse family produced by various species of Streptomyces. Some members of this family exhibit antifungal activity, anticancer activity, or anticoccidial activity.[1] Their useful activity has made these compounds attractive synthetic objectives. Recently, total syntheses of nanaomycin D (**1**), nanaomycin A (**2a**), kalafungin, frenolicin, deoxyfrenolicin (**2b**), and the enantiomer of griseusin (**3**) have been



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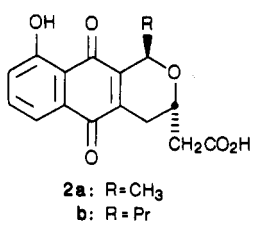
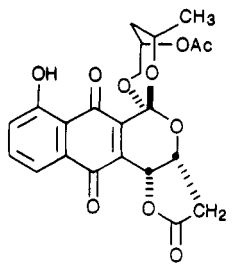


2a: R=CH_3
b: R=Pr



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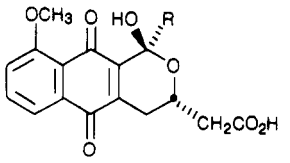

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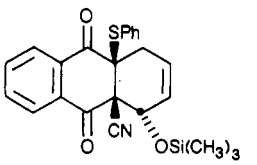
achieved.[2] Our synthesis of **1** and kalafungin was based on the addition of an alkoxyfuran to an activated naphthoquinone.[3] While this strategy provided a valuable entry to the lactone-containing pyranoquinones, it could not be extended to the synthesis of **2** and **3**.[4] Interestingly, however, the lactone-containing pyranoquinones have been prepared from the corresponding acids (e.g., **1** has been synthesized from **2a**). This transformation occurs under quite mild conditions and may be related to the biogenetic pathway.[5] In a related study, we had observed that Diels–Alder adduct **5** was extremely unstable to base and



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that it underwent a facile retro-aldol reaction.[6] In light of the above information, we reasoned that a hemiketal intermediate such as **4** might enable us to synthesize the entire class of compounds, provided that the hemiketal could be selectively reduced. The hemiketal, in turn, might be directly prepared by a Diels–Alder reaction followed by a retro-Claisen reaction. This plan has now been reduced to practice; the successful synthetic route is illustrated in Scheme I.

The cyanophthalide **6** was prepared by a modification of the Li procedure.[7] Deprotonation of **6**, followed by Michael addition with methyl vinyl ketone (MVK) and an intramolecular Claisen reaction, afforded a hydroquinone which could be oxidized with ceric ammonium nitrate (CAN) to quinone **7a**.[8] The yield of quinone from **6** was 66%. The best conditions for this annulation involved the addition of solid potassium *tert*-butoxide in portions to a cold solution of **6** and MVK in dry Me_2SO. These conditions represent a considerable improvement over our previously reported procedure that afforded **7a** in only 25% yield.[9] As expected, the Diels–Alder reaction of **7a** with the ketene acetal derived from ethyl crotonate[10] proceeded cleanly and rapidly at ambient temperature. The NMR of the unpurified product showed only three singlets for the *t*-$BuMe_2SiO$ group. The retro-Claisen reaction was also quite facile with 2 equiv of tetrabutylammonium fluoride in THF at 0 °C. The cis crotonate subunit that was liberated by the retro-Claisen reaction rapidly reacted with the neighboring phenol to produce **9a**. This cyclization had previously been observed by both Yoshii and Uno. They avoided this cyclization by protecting the phenol. For our considerations, however, this cyclization was a desirable reaction. Oxidation of **9a** with CAN in aqueous acetonitrile at ambient temperature produced the key hemiketal **10a** in 71% yield from **7a**. Both the proton and the carbon NMR spectra of **10a** indicated that only one hemiketal was present. The structure of **10b** (R = Pr) was determined by X-ray crystallography.[11] It supports this structure which was initially

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(3) Kraus, G. A.; Roth, B. *J. Org. Chem.* **1978**, *43*, 4923.
(4) A variety of conditions were examined (H_2, Pd/C or Pt/C; Li, NH_3; Et_3SiH, BF_3·Et_2O; Zn, HOAc). These experiments were done by Dr. James MacMillan.
(5) Tanaka, H.; Marumo, H.; Nagai, T.; Okada, M.; Taniguchi, K.; Omura, S. *J. Antibiot.* **1975**, *28*, 925 and references therein.
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(7) Li, T.-T.; Wu, Y. L.; Walgrove, T. C. *Tetrahedron* **1984**, *40*, 4701.
(8) Ho, T.-L.; Hall, T. W.; Wong, C. M. *Chem. Ind. (London)* **1972**, 729.
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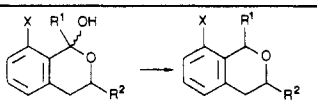
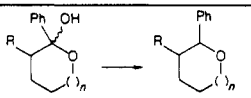
Table I. Reduction of Hemiketals to Ethers



entry	X	R^1	R^2	% yield[a]	cis/trans ratio	
1	OH	CH_3	CH_3	93	100:0	13
2	H	CH_3	*i*-Pr	70	100:0	14
3	H	Ph	CH_3	86	10:1	15
4	H	Ph	*i*-Pr	75	100:0	16
5	H	CH_3	CH_3	88	100:0	17

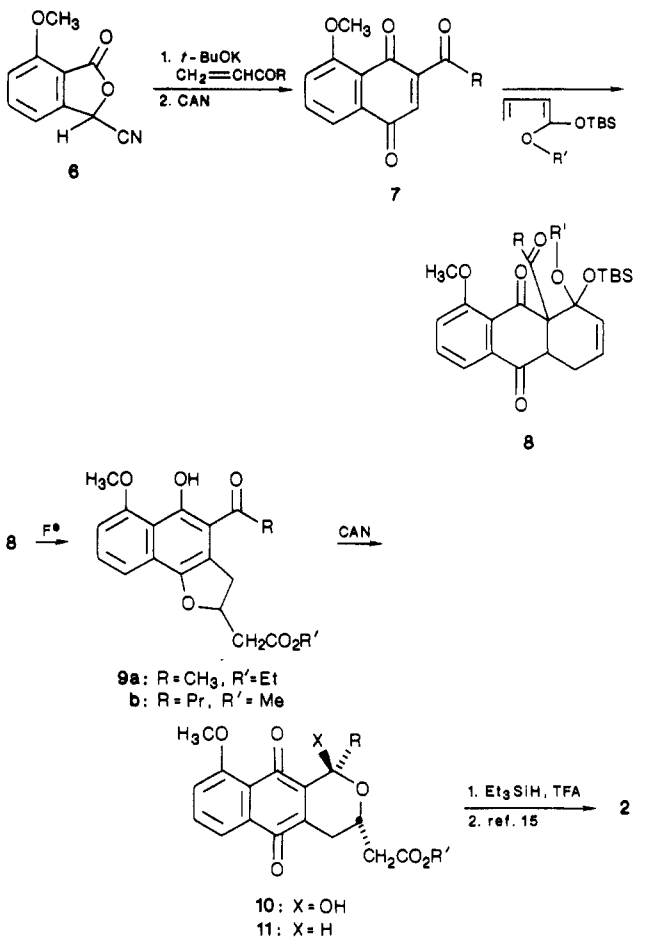


entry	R	*n*	% yield	cis/trans ratio	
6	CH_3	0	74	1:1	18
7	CH_3	1	75	100:0[18]	19

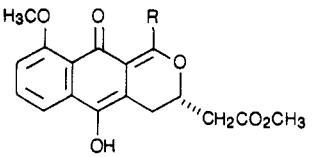
assigned on the basis of the anomeric effect.

The reduction of a hemiacetal unit to an ether has been studied by several researchers.[12] We studied this transformation in the context of converting a lactone to a cyclic ether.[13] The reduction of a hemiketal to a cyclic ether would introduce a new stereogenic center. Although Kishi has reported an interesting example in the carbohydrate area, no studies on simpler alicyclic systems appear to have been reported.[14] We initially examined the stereochemical consequences of this reduction on several model systems. The results are illustrated in Table I. The results show a strong preference for the production of an ether in which the two groups are cis. All results are consistent with axial delivery of hydride from Et_3SiH. This is opposite to the desired relative stereochemistry; however, the acid-catalyzed epimerization to the trans orientation has already been documented in related pyranonaphthoquinones.[17] The ionic hydrogenation conditions (triethylsilane, CF_3CO_2H) afforded a 95% yield of 11. This deoxygenation

Scheme I



reaction is considered to proceed via a highly ordered transition state involving all three reactants; however, in this case the formation of dienol **12** followed by tautomerization to **11** is a distinct possibility and cannot be ruled out. The NMR spectrum of quinone **11** (R = CH_3, R' = Me) is identical[2a] with ours. Semmelhack[15] had already reported the simultaneous cleavage of the methyl ether and



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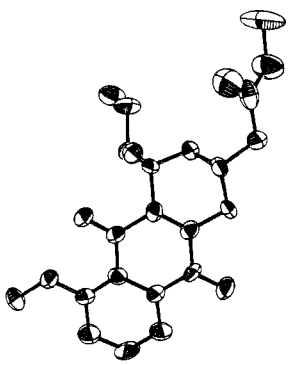
(11) ORTEP drawing of **10b**.



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(18) An authentic sample of **19** and its trans isomer was obtained from 2-methyl-δ-valerolactone by (1) PhMgCl, THF, 0 °C; (2) $LiAlH_4$, THF, 0 °C; (3) TsCl, Et_3N, cat. DMAP, CH_2Cl_2; (4) NaH, THF, 0–25 °C. As expected by Cram's rule, the cis isomer predominated in a 3:1 ratio. The obtention of **19** is consistent with axial delivery of hydride (Et_3SiH) to an intermediate cation with the methyl group in an axial position to avoid $A^{1,2}$ strain.

partial epimerization with boron tribromide. While we obtained the desired phenol as a 2.0–2.5:1 ratio of trans/cis isomers, we also identified approximately 5% of a monobrominated product. This latter side product could be reduced by using 5% Pd/C in ethanol to the methyl ester of **2a**. The methyl ester of **2a** has been hydrolyzed to **2a** by using dilute sodium hydroxide.[15]

The synthesis of deoxyfrenolicin began with the reaction of **6** with propyl vinyl ketone. Oxidation to quinone **7b**, followed by Diels–Alder/retro-Claisen reaction to **9b** and oxidation and reductive deoxygenation afforded **11b** in 32% overall yield from **6**. Quinone **11b** was stereochemically homogeneous as evidenced by carbon NMR. Again, the only isomer produced by the reductive deoxygenation was the cis isomer. Quinone **11b** was then reacted with BBr_3 in hexanes. In this case only the trans isomer was obtained. Again, a small amount of brominated product was isolated. This could be converted to the methyl ester of deoxyfrenolicin with 5% Pd/C. The ester has been hydrolyzed to furnish deoxyfrenolicin.[15]

This route is the most direct and efficient route yet reported. It is extremely direct, generating the pyranoquinone nucleus in only seven steps. Additionally, these syntheses represent the first use of the Diels–Alder/retro-Claisen (DARC) strategy in natural products synthesis. The extension of this strategy to the synthesis of more complicated pyranoquinones such as lactoquinomycin[16] is currently in progress.

Experimental Section

Unless otherwise noted, materials were obtained from commercial suppliers and were used without purification. Dichloromethane was distilled from phosphorus pentoxide. Infrared spectra were determined on a Beckman IR-4250 spectrometer. Nuclear magnetic resonance spectra were determined on a Nicolet 300-MHz instrument. Carbon-13 NMR spectra were determined on a JEOL FX-90Q Fourier transform instrument. High resolution mass spectra were determined on a Kratos mass spectrometer. Elemental-analyses were performed by Galbraith Laboratories, Inc., Knoxville, TN.

General Procedure for the Formation of Cyclic Ethers. To a solution of the lactone (1 equiv) in dry tetrahydrofuran (5 mL/mmol) at −78 °C was added dropwise methyllithium (1.1 equiv) or phenylmagnesium chloride (1.1 equiv). The solution was stirred at −78 °C for 2 h and then quenched at −78 °C (methyllithium cases) or stirred at −78 °C for 1 h and then allowed to warm to 0 °C before the quench (PhMgCl cases). Acetic acid (1.1 equiv) was then added and the reaction was poured into ice–water. The aqueous layer was extracted three times with chloroform. The combined organic extracts were dried over sodium sulfate, filtered, and concentrated. The crude hemiketal was taken directly on to the reduction without purification. The crude lactol (1 equiv) was dissolved in methylene chloride (25 mL/equiv) and cooled to −78 °C. Trifluoroacetic acid (3 equiv) was added dropwise and the solution was stirred for 15 min. Triethylsilane (3 equiv) was added and the reaction was stirred at −78 °C for 30 min and then allowed to warm to ambient temperature over 2 h. The solution was then poured into ice–water. The aqueous layer was extracted three times with chloroform. The combined organic extracts were dried and concentrated. The crude product was purified by chromatography on silica gel using either hexanes/ethyl acetate or hexanes/methylene chloride.

2-Phenyl-3-methyltetrahydropyran (19): 300-MHz ^{1}H NMR ($CDCl_3$) δ 0.74 (d, J = 7 Hz, 3 H), 1.32–1.38 (m, 1 H), 1.74–1.81 (m, 1 H), 1.84–2.07 (m, 3 H), 3.57–3.66 (m, 1 H), 4.13–4.23 (m, 1 H), 4.55 (d, J = 2 Hz, 1 H), 7.17–7.33 (m, 5 H); IR (film) 2935, 1450 cm^{-1}; HRMS, m/e calcd 176.1201, found 176.1203.

8-Hydroxy-1,3-dimethyl-3,4-dihydro-1*H*-2-benzopyran (13): 300-MHz ^{1}H NMR ($CDCl_3$) δ 1.38 (d, J = 7 Hz, 3 H), 1.55 (d, J = 7 Hz, 3 H), 2.42–2.82 (m, 2 H), 3.78–3.90 (m, 1 H), 4.82–4.92 (bq, J = 7 Hz, 1 H), 6.62–6.71 (m, 2 H), 6.97–7.08 (m, 1 H); IR (Nujol mull) 3350, 1585, 1460, 782, 722 cm^{-1}; MS, m/e 134, 163, 178; HRMS, m/e calcd 178.09938, found 178.09903; mp 111–112 °C (ether/hexanes).

1-Phenyl-3-methyl-3,4-dihydro-1*H*-2-benzopyran (15): 300-MHz ^{1}H NMR ($CDCl_3$) δ 1.23 and 1.40 (d, J = 6 Hz for both isomers, 3 H), 2.73–2.97 (m, 2 H), 3.97–4.10 (m, 1 H), 5.74 and 5.93 (br s, 1 H), 6.66–7.38 (m, 9 H); IR (film) 2982, 1490, 1450, 1065, 640, 598 cm^{-1}; MS, m/e 105, 147, 165, 179, 224.

1-Phenyl-3-(1-methylethyl)-3,4-dihydro-1*H*-2-benzopyran (16): 300-MHz ^{1}H NMR ($CDCl_3$) δ 1.00 (d, J = 7 Hz, 3 H), 1.03 (d, J = 7 Hz, 3 H), 1.82–1.90 (m, 1 H), 2.74–3.00 (m, 2 H), 3.53–3.62 (m, 1 H), 5.68 (s, 1 H), 6.68 (d, J = 7.5 Hz, 1 H), 6.98–7.39 (m, 8 H); IR (film) 2950, 1490, 1452, 1082, 1068, 740, 696 cm^{-1}; MS, m/e 165, 181, 209, 252; HRMS, m/e calcd 252.1514, found 252.1513.

1-Methyl-3-(1-methylethyl)-3,4-dihydro-1*H*-2-benzopyran (14): 300-MHz ^{1}H NMR ($CDCl_3$) δ 0.97 (d, J = 6 Hz, 3 H), 1.10 (d, J = 6 Hz, 3 H), 1.52 (d, J = 6 Hz, 3 H), 1.73–1.86 (m, 1 H), 2.65–2.82 (m, 2 H), 3.27–3.36 (m, 1 H), 4.76–4.86 (bq, J = 6 Hz, 1 H), 7.05–7.23 (m, 4 H); IR 2960, 1490, 1450, 1114, 1110, 760, 732 cm^{-1}; MS, m/e 91, 118, 129, 147, 157, 175, 190; HRMS, m/e calcd 190.13577, found 190.13556.

2-Phenyl-3-methyltetrahydrofuran (18): 300-MHz ^{1}H NMR ($CDCl_3$) δ 0.60 and 1.08 (3 H), 1.65–1.85 (m, 1 H), 2.02–2.26 (m, 1 H), 2.45–2.57 (m, 1 H), 3.88–4.22 (m, 2 H), 4.28 (d, J = 8 Hz, $^1/_2$ H), 4.95 (d, J = 6 Hz, $^1/_2$ H), 7.2–7.35 (m, 5 H); IR (film) 2960, 1450, 1092, 1044 cm^{-1}; MS, m/e 117, 147, 162; HRMS, m/e calcd 162.1045, found 162.1041.

1,3-Dimethyl-3,4-dihydro-1*H*-2-benzopyran (17): 300-MHz ^{1}H NMR ($CDCl_3$) δ 1.37 (d, J = 6 Hz, 3 H), 1.56 (d, J = 6 Hz, 3 H), 2.63–2.82 (m, 2 H), 3.78–3.88 (m, 1 H), 4.86 (q, J = 6 Hz, 1 H), 7.04–7.22 (m, 4 H); IR (film) 2985, 1490, 1445, 1112, 734 cm^{-1}; MS, m/e 117, 129, 147, 161, 162; HRMS, m/e calcd 162.10447, found 162.1038.

2-Acetyl-1,4-dihydroxy-8-methoxynaphthalene. To a solution of phthalide **6** (2.15 g, 11.37 mmol) and methyl vinyl ketone (1.04 mL, 12.5 mmol) in 57 mL of dimethyl sulfoxide at ambient temperature was added potassium *tert*-butoxide (1.945 g, 17.35 mmol). After stirring 90 min at ambient temperature, an equal portion of potassium *tert*-butoxide was added and stirring continued for 90 min. The reaction mixture was diluted with 30 mL of diethyl ether and acidified with excess 2 N HCl. The resulting yellow solution was poured into 500 mL of ice water and extracted eight times with 50-mL portions of diethyl ether. The organic extracts were combined, washed with brine, and dried. The solvents were removed in vacuo and the residue chromatographed on 175 g of silica gel, eluting with 2.5:1 hexanes/ethyl acetate to afford 1.74 g (66%): 300-MHz ^{1}H NMR ($CDCl_3$) δ 2.65 (s, 3 H), 4.05 (s, 3 H), 6.96 (d, 1 H, J = 7.8 Hz), 7.16 (s, 1 H), 7.54 (t, 1 H, J = 8.1 Hz), 7.82 (d, 1 H, J = 8.1 Hz), 8.14 (s, 1 H), 13.6 (s, 1 H); IR ($CDCl_3$) 3600–3400, 1640, 1600 cm^{-1}.

Ethyl [5-Acetyl-6-hydroxy-7-methoxy-3,4-dihydronaphtho[1,2-*b*]furan-3-yl]acetate (9a). To the hydroquinone (540 mg, 2.32 mmol) in 25 mL of acetonitrile at ambient temperature was added ceric ammonium nitrate (2.92 g, 5.34 mmol) in 4 mL of water. After being stirred for 20 min at ambient temperature, the reaction mixture was diluted with 20 mL of methylene chloride and poured into 100 mL of water containing 10 mL of a 1 M pH 7.2 phosphate buffer. The layers were separated and the aqueous phase was extracted with 30 mL of methylene chloride. The organic extracts were combined, washed with water, dried over magnesium sulfate, and concentrated in vacuo. The quinone was diluted with 19 mL of methylene chloride and transfered to a dry two-necked flask under positive argon pressure. To this solution was added 1-ethoxy-1-[(*tert*-butyldimethylsilyl)oxy]butadiene (1.12 g, 4.9 mmol) in 1 mL of methylene chloride at −78 °C. The reaction mixture was stirred for 15 min at −78 °C, warmed slowly to ambient temperature, and then recooled to 0 °C. The resulting pale yellow solution was treated sequentially with 10 mL of acetonitrile, 5 mL of a pH 7.5 phosphate buffer, and tetrabutylammonium fluoride (4.8 mL of a 1.0 M solution of THF). The resulting dark brown solution was warmed to ambient temperature, acidified with 2 N HCl, and poured into 100 mL of brine. The aqueous phase was extracted with three 40-mL portions of diethyl ether, and the organic extracts were combined, washed with brine, and dried over magnesium sulfate. The solvents were removed in vacuo and the

residue flash chromatographed on silica gel eluting with 2.7:1 hexanes/ethyl acetate to afford 613 mg (77%) of **9a**, yellow needles from ethyl acetate/hexanes: mp 103–104.5 °C; 300-MHz ^{1}H NMR ($CDCl_3$) δ 1.27 (t, 3 H, J = 6.9 Hz), 2.65 (s, 3 H), 2.68 (dd, 1 H, J = 15.6 and 6.3 Hz), 2.87 (dd, 1 H, J = 15.6 and 7.2 Hz), 3.23 (dd, 1 H, J = 16.8 and 7.2 Hz), 3.69 (dd, 1 H, J = 16.8 and 9.6 Hz), 4.01 (s, 3 H), 4.19 (q, 2 H, J = 6.9 Hz), 5.24 (m, 1 H), 6.75 (d, 1 H, J = 7.5 Hz), 7.30–7.50 (m, 2 H), 11.35 (s, 1 H); IR (film) 3005, 1730, 1610, 1390, 1310, 1220, 1150, 1080 cm^{-1}; ^{13}C NMR 14.37, 32.50, 38.38, 41.09, 56.22, 60.64, 78.87, 105.40, 114.75, 115.08, 116.26, 118.56, 124.94, 128.62, 146.79, 154.03, 157.72, 170.40, 201.11 ppm; MS, m/e 344, 270, 257, 241; HRMS, m/e calcd 344.12599, found 344.1259.

***trans*-Ethyl [1-Hydroxy-9-methoxy-1-methyl-5,10-dioxo-3,4,5,10-tetrahydronaphtho[2,3-*c*]pyran-3-yl]acetate (10a).** To a solution of **9** (613 mg, 1.78 mmol) in 40 mL of acetonitrile at ambient temperature was added ceric ammonium nitrate (2.36 g, 4.30 mmol) in 8.5 mL of water. The reaction mixture was stirred 30 min at ambient temperature and poured into 50 mL of water containing 5 mL of a pH 7.5 phosphate buffer, and the layers were separated. The aqueous phase was extracted twice with 30-mL portions of methylene chloride, and the organic extracts were combined, washed with water, and dried over magnesium sulfate. The solvents were removed in vacuo and the residue was crystallized from methylene chloride/hexanes to afford 553 mg (91%) of **10a** as yellow needles: mp 153–154 °C; 300-MHz ^{1}H NMR ($CDCl_3$) δ 1.29 (t, 3 H, J = 7.2 Hz), 1.73 (s, 3 H), 2.28 (dd, 1 H, J = 18.7 and 11.1 Hz), 2.64 (dd, 1 H, J = 15.6 and 6.6 Hz), 2.76 (dd, 1 H, J = 15.6 and 6.6 Hz), 2.88 (dd, J = 18.7 and 2.7 Hz), 3.87 (br s, 1 H), 4.02 (s, 3 H), 4.19 (q, 2 H, J = 7.2 Hz), 4.48 (m, 1 H), 7.32 (dd, 1 H, J = 8.1 and 0.9 Hz), 7.64–7.80 (m, 2 H); IR ($CHCl_3$) 3600–3400, 3010, 1730, 1655, 1585, 1270 cm^{-1}; ^{13}C NMR 14.02, 27.64, 28.23, 40.09, 56.71, 60.69, 65.00, 94.30, 118.34, 119.06, 120.01, 133.97, 135.27, 140.35, 146.33, 159.84, 170.19, 182.02, 182.18 ppm; MS, m/e 342, 296, 268, 244, 229, 201; HRMS, m/e calcd 360.12091, found 360.12032.

***cis*-Ethyl [9-Methoxy-1-methyl-5,10-dioxo-3,4,5,10-tetrahydro-1*H*-naphtho[2,3-*c*]pyran-3-yl]acetate (11a).** To a solution of **10a** (102 mg, 0.30 mmol) in 15 mL of methylene chloride at −78 °C was added trifluoroacetic acid (0.14 mL, 1.8 mmol), and the resulting slurry was stirred at −78 °C for 15 min. To the slurry was added triethylsilane (0.29 mL, 1.8 mmol) at −78 °C. The reaction mixture was slowly warmed to ambient temperature over 3 h. The resulting yellow solution was concentrated in vacuo and the residue crystallized from diethyl ether/hexanes to afford 93 mg (95%) of **11a** as yellow needles: mp 118–119 °C [lit.[2c] mp 113–115 °C]; 300-MHz ^{1}H NMR ($CDCl_3$) δ 1.29 (t, 3 H, J = 7.2 Hz), 1.52 (d, 3 H, J = 6.6 Hz), 2.28 (ddd, 1 H, J = 18.1, 10.5, and 3.7 Hz), 2.60 (dd, 1 H, J = 15.6 and 7.5 Hz), 2.70 (dd, 1 H, J = 15.6 and 7.5 Hz), 2.83 (apparent dt, 1 H, J = 18.1, 2.5, and 2.5 Hz), 3.93 (m, 1 H), 4.00 (s, 3 H), 4.19 (q, 2 H, J = 7.2 Hz), 4.87 (m, 1 H), 7.28 (br d, 1 H, J = 8.4 Hz), 7.64 (t, 1 H, J = 7.8 Hz), 7.73 (dd, 1 H, J = 7.8 and 0.9 Hz); IR (film) 2980, 1730, 1660, 1585, 1270 cm^{-1}; MS, m/e 344, 298, 270, 257, 240; HRMS, m/e calcd 344.12599, found 344.1255.

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Supplementary Material Available: Experimental conditions and spectral data for compounds in the deoxyfrenolicin series (**7b**, **9b**, **10b**, and **11b**) (7 pages). Ordering information is given on any current masthead page.

Stereospecific Arylation of Alkenylsilanes with Arylpalladium Acetates

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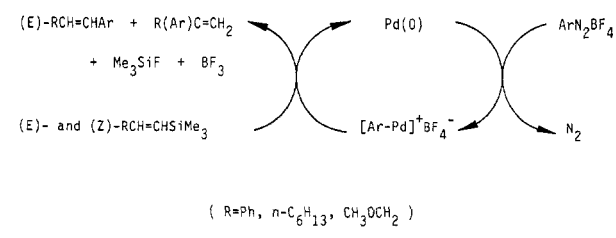
Alkenyltrimethylsilanes ((*E*)- and (*Z*)-RCH=CHSiMe$_3$: R = H, Ph, *n*-C_6H_{13}, and CH_3OCH_2) stereospecifically reacted at 40 °C or room temperature with in situ generated phenylpalladium acetate to produce R(Ph)C=CHSiMe$_3$ and RCH=C(Ph)SiMe$_3$ with inversion of their geometry. The arylation of CH_2=CHSiMe$_3$ with arylpalladium acetates gave (*E*)-ArCH=CHSiMe$_3$ (Ar = XPh; X = H, 4-Me, 4-MeO, 4-Br, 4-I, 4-EtOCO, and 4-NO_2) in good yields.

Stereospecific transformations of alkenylsilanes by a variety of electrophiles have been developed and utilized in organic synthesis.[1] However, little is known concerning the reaction of alkenylsilanes with transition-metal organometallics or salts whose catalysis has an important role in C–C coupling of main group organometallics with carbon-based electrophiles.[2]

Reactions of (*E*)-PhCH=CHSiMe$_3$ or (*E*)-PhCH=CHSiF$_5^{2-}$ with palladium salts have been reported to give (*E*)-PhCH=CHPd intermediates through an addition–elimination[3] or transmetalation[4] mechanism. Palladium-catalyzed reactions of CH_2=CHSiMe$_3$ with aryl iodides yield aryl-desilylated products, ArCH=CH_2.[5] Recently

Scheme I



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