In summary, we have developed new and mild reaction conditions for glycosylation of iodo sulfonamides, which has enabled us to successfully synthesize sialyl-Lewis X antigen. Current studies include the elaboration of glycals **5–7** to the synthesis of gangliosides[10] and glycopeptides.[11]

Acknowledgment. This work was supported by the National Institutes of Health, Grant No. HL-25848 (S.J.D.). We also thank Japan Tobacco, Inc., for providing sabbatical and research support for K.K.

Supplementary Material Available: Complete experimental details and analytical and spectral data for all new compounds, **1** and **3–7** (11 pages). Ordering information is given on any current masthead page.

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(9) Prepared in two steps from D-lactal: (1) 2 equiv of TBDMSCl, cat. DMAP, pyridine (67% yield); (2) $(Bu_3Sn)_2O$, benzene, reflux, percolation of refluxing solvents through 4-Å molecular sieves.

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A Remarkable Cyclopropanation: The Total Synthesis of Myrocin C

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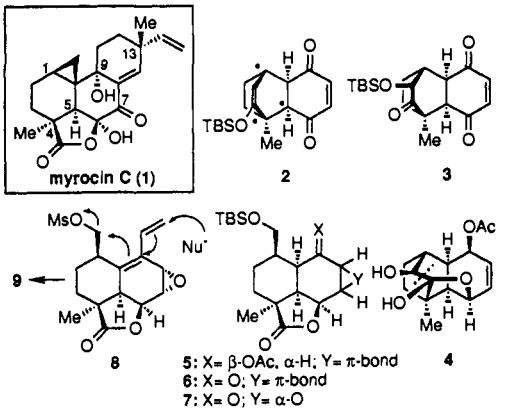
Received June 9, 1992

Myrocin C (**1**) is a structurally novel pentacyclic diterpene isolated in 1988 from the soil fungus *Myrothecium verrucaria* strain no. 55.[1] This antitumor antibiotic exhibits half the activity of mitomycin C in an in vivo tumor inhibitory screen.[2] Our interest in the synthesis of myrocin C stemmed from two considerations. The confluence of its structural features posed considerable synthetic challenges which invited several potentially interesting solutions. Furthermore, a proposed mechanism for the biotriggering of **1** could be inferred,[3] the testing of which required access to 6-desoxymyrocin C (**18**). In this paper we report the total synthesis of racemic **1** by way of **18**.

A critical reaction of the synthesis occurs in the first step wherein compound **2** was obtained from Diels–Alder cycloaddition (THF, room temperature, 5 days, 94%) of *p*-benzoquinone with 2-[(*tert*-butyldimethylsilyl)oxy]-1-methylcyclohexa-1,3-diene[4]

Scheme I



(note the stereochemical homology between C-1, C-4, and C-5 of **1** and the corresponding centers of **2**). Oxidation[5] (2,2-dimethyldioxirane,[6] acetone/CH_2Cl_2) of **2** afforded **3**, which upon reduction[7] ($NaBH_4$, $CeCl_3 \cdot 7H_2O$, MeOH), acetylation (Ac_2O, Et_3N, DMAP, CH_2Cl_2), and desilylation (TBAF, AcOH, THF) gave **4** (59% overall from **2**). Cleavage of the vicinal "diol" linkage ($NaIO_4$, THF/H_2O) followed by reduction ($NaBH_4$, MeOH) of the lactone aldehyde and protection (TBSOTf, Et_3N, CH_2Cl_2) of the primary alcohol afforded **5** in 99% overall yield from **4**. Deacetylation (NaOMe, MeOH) and subsequent oxidation (PDC,[8] CH_2Cl_2) afforded enone **6**, which was stereospecifically epoxidized[9] (H_2O_2, NaOH, MeOH) to afford epoxy ketone **7** (66% overall yield from **5**). The resulting oxiranyl linkage exhibited surprising stability to the following sequence: (i) enol triflation[10] (NaHMDS, Tf_2NPh, THF), (ii) cross-coupling[11] ($Bu_3SnCH{=}CH_2$, $PdCl_2(PPh_3)_2$, LiCl, THF), (iii) desilylation (TBAF, AcOH, THF), and (iv) mesylation (MsCl, Et_3N, DMAP, CH_2Cl_2). Compound **8** was thus obtained in 40% overall yield from **7** (Scheme I).

The elements were then in place for the defining reaction of the synthesis. Upon treatment of compound **8** with (trimethylstannyl)lithium[12] in THF, cyclopropyl dienol **10** was produced in 66% yield, presumably through the intermediacy of allylstannane **9**.[13] It will be recognized that this transformation accomplishes installation of the cyclopropane while liberating the C-7 alcohol. The latter, of course, is destined to become the C-7 ketone in **1**. However, before that oxidation, this alcohol serves another important strategic end. Thus, condensation (DCC, DMAP, CH_2Cl_2) of **10** with (*E*)-3-methyl-4-oxo-2-butenoic acid[14] afforded **11**, which upon thermolysis (PhH, reflux, 13 h) gave, by *endo* addition of the aldehyde function, the adduct **12**. Wittig olefination ($Ph_3P{=}CH_2$, THF) provided **13** (79% overall yield from **10**) in which C-14 had undergone complete epimerization to the β-configuration. *This intramolecular Diels–Alder reaction,[15] achieved through the C-7 ester tether, has not only provided a usefully functionalized C-ring but has also enabled rigorous control of the remote C-13 chiral center.*

The now extraneous carbon (C-21) was excised as follows. Reduction (DIBAL-H, CH_2Cl_2) of **13** gave a bislactol which upon selective oxidation (PDC, CH_2Cl_2) afforded compound **14** (74%).

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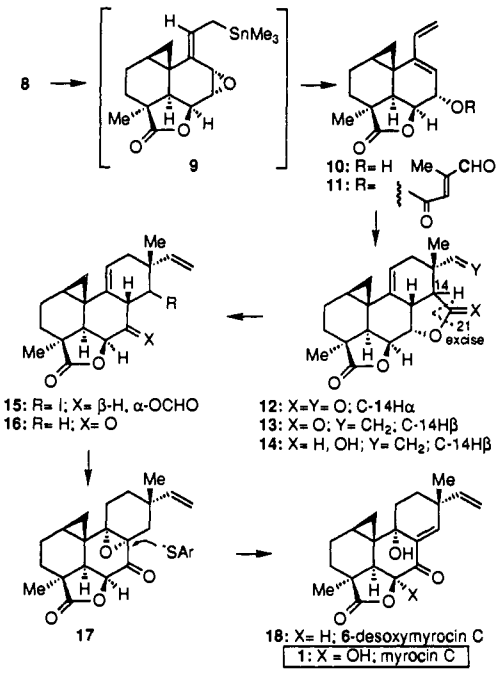
Scheme II



Photolytically mediated iodinative cleavage[16] ($PhI(OAc)_2$, I_2, cyclohexane) of the lactol linkage gave rise to iodo formates **15** (7:1 β/α), which upon reductive deiodination/deformylation (neat[17] Bu_3SnH, AIBN) and oxidation (Dess-Martin periodinane,[18] CH_2Cl_2) provided ketone **16**. Concomitant enone conjugation and stereospecific epoxidation (H_2O_2, NaOH, MeOH) gave **17** in 50% overall yield from **14** (Scheme II).

Oxirane opening (4-OMePhSAlMe$_3$Li,[19] THF) followed by sulfoxide formation (2,2-dimethyldioxirane, acetone/CH_2Cl_2) and spontaneous elimination provided desoxymyrocin C (**18**) in 55% overall yield. Finally, C-6 hydroxylation[20] (O_2, *t*-BuOK, THF/*t*-BuOH) was achieved via the presumed, but uncharacterized, C-6 hydroperoxide which was immediately reduced ($P(OEt)_3$, THF) to give *dl*-myrocin C (**1**), mp >214 °C dec, in 68% yield. While the spectral properties of the fully synthetic material corresponded very closely to those recorded for the natural product, a sample of the latter was not available to us for direct comparative measurements. *That the total synthesis of racemic* **1** *had in fact been achieved was rigorously demonstrated by a single-crystal X-ray determination of our fully synthetic material.*[21]

We shall in due course report on the mechanistic aspects of the cyclopropanation reaction as well as the interesting chemistry of **18** and **1** and the possible implications of the latter findings on the mode of action of myrocin C.

Acknowledgment. This work was supported by NIH Grant No. CA 28824. We thank Professor Mitsuru Nakayama (University of Osaka Prefecture, Japan) and Dr. Yuan-Hsun Hsu (Development Center for Biotechnology, Taiwan) for providing us with spectra of the natural product and Gayle Schulte (Yale University Instrumentation Center) for X-ray structure determinations. NSF Predoctoral and Kent (Yale University) Fellowships to M.Y.C.-M. are gratefully acknowledged.

Supplementary Material Available: A chart of reactions including specific conditions and yields for all transformations reported herein with listings of compiled analytical data for **2**, **10**, **13**, **18** and **1**, as well as well as ^1H and ^{13}C NMR spectra of synthetic and natural **1** (8 pages). Ordering information is given on any current masthead page.

n-Pentenyl Glycoside Methodology for Rapid Assembly of Homoglycans Exemplified with the Nonasaccharide Component of a High-Mannose Glycoprotein[1,2]

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Received May 18, 1992

Complex saccharides play critical roles in biological regulation,[3] and the triantenary oligosaccharide **1** which, though well-known as one of several high-mannose glycoproteins occurring in animals and plants,[4,5] now attracts special attention because of its presence on the conserved V3 loop of the viral coat of HIV1, known as GP-120.[6]

The mannan moiety of **1** can be dissected into three zones (Scheme I) whose components carry three, two, and one sugar units A, B, and C, respectively. Further retroanalysis of A leads to the retron **2** with permanent protecting groups at O2 and O4 and different temporary protecting groups at O3 and O6. Retrons B and C lead to the same synthon **3**, where the C2 ester serves for temporary protection, as required in B, or permanent, as required in C. Thus the nonasaccharide component of **1** could conceivably be constructed from only two mannopyranose precursors, **2** and **3**. In this manuscript we describe the realization of this objective based on the novel chemistry of *n*-pentenyl glycosides.

The armed/disarmed strategy for saccharide coupling emanated from our exploratory work on NPGs,[7] and two developments from

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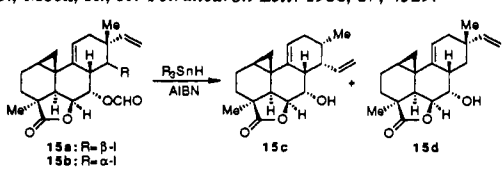

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(21) Crystallographic parameters and specifications will be reported in a subsequent disclosure.

(1) This work was supported by grants from the NIH (GM 41071, AI-31863) and NSF (CHE 8920003).

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