that are enhanced by heme-His(F8) interactions. Moreover, because HbO_2, HbCO, and metHb lack the modes at ~250 cm^{-1} observed in the corresponding Mb species, their enhancement must be associated with differences in heme-histidine conformation between Mb and Hb. Similar arguments hold for the native and partially unfolded (low pH) forms of MbCO. We tentatively suggest that the intensity of the ~250-cm^{-1} mode is a probe of the eclipse angle between the histidine plane and the N_p-N_p axis.

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Registry No. Fe, 7439-89-6; His, 71-00-1; heme, 14875-96-8.

Communications to the Editor

Enantioselective Synthesis of (+)-3-Isorauniticine via a Catalytic Tandem "Palladium-Ene"/Carbonylation Reaction

Wolfgang Oppolzer,* Hugues Bienaymé, and Arielle Genevois-Borella

Département de Chimie Organique, Université de Genève CH-1211 Genève 4, Switzerland

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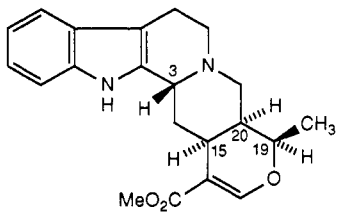
The heteroyohimbine alkaloid 3-isorauniticine, isolated from *Corynanthe mayumbensis*, has been shown to possess constitution and relative configuration **1**.[1] We present here the first total synthesis of (+)-**1**,[2] thereby assigning its absolute configuration.[3]



1

The cornerstone of our strategy is an intramolecular Pd-catalyzed allylation/carbonylation process, recently employed for a synthesis of (±)-pentalenolactone E.[4] For the preparation of **1** we envisaged control, in this key step, of the configuration of developing centers C(15) and C(20) by means of a preexisting center C(3).[5] To set up center C(3) we took advantage of a convenient multigram approach to enantiomerically pure α-amino acids (Scheme I).[6]

Thus, C-alkylation of commercially available chiral glycinate equivalent **2**[6,7] with allyl iodide/LiOH under phase-transfer conditions[6b] followed by acidic removal of the N-protecting group and N-acylation with mesitylenesulfonyl chloride provided crystalline sulfonamide **3**[8] (69% from **2**, mp 151-152 °C). N-Alkylation of **3** with (*Z*)-1-bromo-4-[(methoxycarbonyl)oxy]-2-butene[9] furnished dienylcarbonate **4** (96% yield).[8] Proceeding to the key reaction, carbonate **4** was subjected to Pd(0)-catalyzed cyclization/carbonylation in acetic acid, giving a 67:22:11 mixture of **5** and two stereoisomers.[10] Flash chromatography (FC) afforded the crystalline major isomer **5**[8] (mp 190-191 °C) in 45-53% yield.

Catalytic hydrogenation of **5** from the less hindered exo face and subsequent Baeyer-Villiger oxidation yielded lactone **6**[8] (mp 141-143 °C, 86% from **5**). We now needed to deprotect first the amino group and then the carboxyl group without affecting the lactone moiety. "Transesterification" of acyl sultam **6** with lithium *p*-nitrobenzyl oxide and FC gave the *p*-nitrobenzyl ester **7**[8] (55%, mp 118-119 °C). Starting from **7**, successive cleavage of the sulfonamide (HF/pyridine[11]), N-alkylation with tryptophyl bromide, and hydrogenolysis furnished carboxylic acid **8**[8] (62% from **7**), which was subjected to a $PhPOCl_2$-mediated Rapoport cyclization,[12] giving pentacyclic lactone **9**[8] (46%, mp 268-271 °C dec) as a single stereoisomer. The transformation **8** → **9** apparently involves decarbonylation of **8** with loss of the C(3) configuration, which is reestablished in the subsequent Pictet-Spengler step.

Finally, formylation of lactone **9** followed by Korte "rearrangement"[2a,c,g,j,13] provided (+)-3-isorauniticine (53% from **9**, hydrochloride: mp 258-260 °C dec, $[\alpha]_D$ = +37.4° (*c* = 0.77, MeOH, *T* = 19.5 °C); lit.[1] mp 277 °C, lit.[1] $[\alpha]_D$ = +25° (*c* = 1, MeOH)). The ^1H NMR, ^{13}C NMR, IR, and CD spectra of synthetic **1** are identical with those of the naturally occurring alkaloid.[14]

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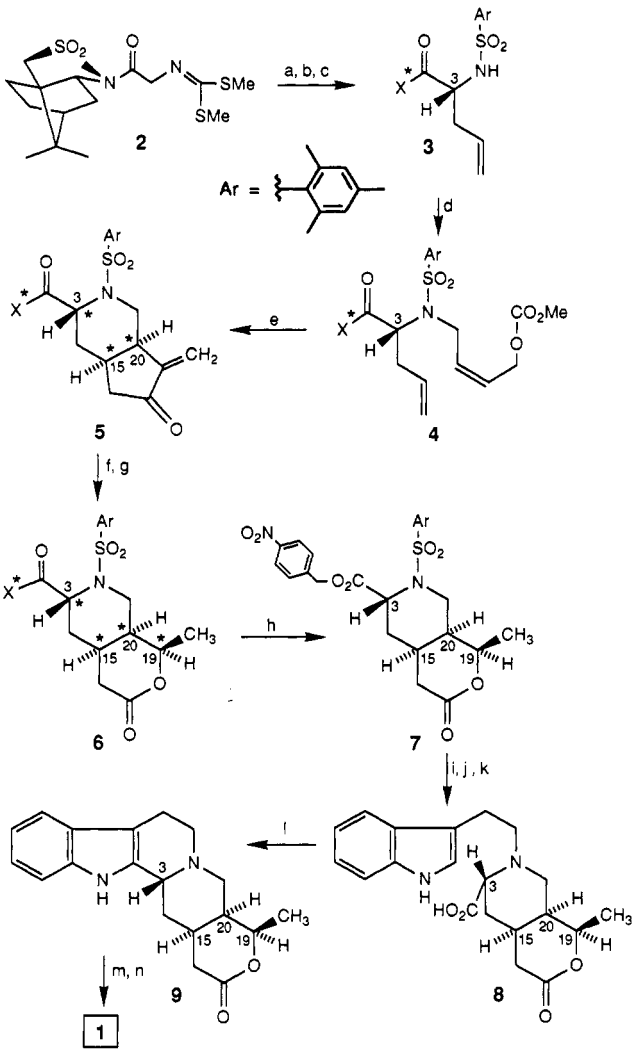
Scheme I[a]



[a] (a) Allyl iodide (1.2 equiv), Bu_4NHSO_4 (1.2 equiv), LiOH (50 equiv), CH_2Cl_2/H_2O (19:1), ultrasound, -7 °C (bath), 6 min. (b) HCl (0.5 N), THF/H_2O (1:1), room temperature, 4 h. (c) Mesitylenesulfonyl chloride (1.5 equiv), pyridine (3.5 equiv), CH_2Cl_2, reflux, 24 h. (d) (*Z*)-1-Bromo-4-[(methoxycarbonyl)oxy]-2-butene (1.2 equiv), NaH (1 equiv), DMF, 0 °C, 12 h. (e) $Pd(dba)_2$ (0.1 equiv), PBu_3 (0.3 equiv), CO (1 atm), AcOH, 80 °C, 3 h. (f) Pd/C (0.1 equiv), H_2 (1 atm), EtOAc, room temperature, 18 h. (g) MCPBA (80%, 1.5 equiv), $NaHCO_3$ (10 equiv), CH_2Cl_2, room temperature, 18 h. (h) *p*-Nitrobenzyl alcohol (1.3 equiv), *n*-BuLi (1 equiv), THF/hexane (25:1), -30 °C, 0.5 h, then addition of **6**, -30 °C → -10 °C, 6 h. (i) Pyridine/70% HF (excess), anisole (2 equiv), room temperature, 8 h. (j) Tryptophyl bromide (1.2 equiv), $NaHCO_3$ (10 equiv), MeCN, 80 °C, 6 h; then addition of further tryptophyl bromide (0.4 equiv), 80 °C, 5 h. (k) Pd/C (0.05 equiv), H_2 (1 atm), EtOH, room temperature, 0.5 h. (l) $PhPOCl_2$ (excess), 105 °C, 4 min, then addition of 1 N aqueous HCl, 70 °C, 10 min. (m) NaHMDS (10 equiv), THF, -78 °C, 2 h, then addition of methyl formate (40 equiv), -78 °C, 1 h, then →0 °C, 4 h. (n) Saturated HCl/MeOH, CH_2Cl_2 (1:9), 120 °C (sealed tube), 24 h, then *p*-TsOH (5 equiv), CH_2Cl_2, reflux, 15 h.

In summary, (+)-3-isorauniticine has been synthesized via a sequence of 14 steps, which highlights once more the preparative utility of sultam-directed asymmetric alkylations[6,15] and of transition-metal-catalyzed carbometalation/carbonylation reactions.[4,5,10,16]

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Supplementary Material Available: Reaction scheme, preparations, and analysis data, including mp, IR, ^{13}C NMR, and MS (9 pages). Ordering information is given on any current masthead page.

Silicon-Mediated Reductive Coupling of Aldehydes and Allylic Alcohols. A Stereoselective Synthesis of Tunicaminyluracil

Andrew G. Myers,* David Y. Gin, and Katherine L. Widdowson

Contribution No. 8488, Arnold and Mabel Beckman Laboratories of Chemical Synthesis California Institute of Technology Pasadena, California 91125

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We report the development of a method for carbon–carbon bond formation between the olefinic terminus of an allylic alcohol and the carbonyl carbon of an aldehyde.[1] This coupling reaction forms the basis of a highly convergent synthesis of tunicaminyluracil (**1**),[2] the undecose core of the tunicamycin antibiotics (tunicamycin C, shown below, is exemplary),[3] from simple carbohydrate-derived precursors.

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