An additional feature that is unique to this catalyst system is the fact that reactions which destroy the catalytically active hydrido complex, such as homolytic cleavage of the Ni–H bond and reactions G and H, produce the catalyst precursor. Thus, the net result of these side reactions would only be to remove catalyst precursor in the form of the crotyl complex. The detection of this complex in the spent catalyst would probably not have been possible if these reactions were not operative.

An important result of this work is the observation that a nickel(II) hydride can react with a nickel(II) allyl to produce olefin and nickel(I) as products. To our knowledge a corresponding reaction has only been demonstrated for the $Co^{III}(CN)_5H^{3-}/Co^{III}(CN)_5(allyl)^{3-}$ system where the products are olefin and $Co^{II}(CN)_5^{3-}$. The importance of such a reaction to nickel chemistry must yet be assessed. Butene apparently is not formed by reaction of phosphite nickel hydrides with the corresponding crotyl complex.[25] This is not surprising since phosphite nickel(I) complexes are unstable with respect to disproportionation, which makes their formation by such a reaction rather less likely.[19,27] It seems quite possible, however, that the reaction may provide a clean route to new tris*phosphine*nickel(I) complexes from readily available (in most cases) phosphine nickel(0) starting materials.

Our observations on the reaction of the nickel(II) hydride formed by protonation of $(Ph_3P)_4Ni$ with butadiene to give the *syn*-η^3-crotyl complex are also interesting in light of Tolman's work on related reactions which shows that the reaction rate of pentacoordinate nickel hydrides can be directly related to the ease with which a vacant coordination site is achieved. The fact that the crotyl complex is formed rapidly indicates that phosphine exchange is rapid if the hydrido species exists in solution as $(Ph_3P)_3Ni(H)X$.

The fact that no C_8 hydrocarbon products, which might arise from metal hydride catalyzed coupling of butene molecules, were ever observed is probably a result of the presence of the large excess of phosphine relative to hydrido complex (recall that 1 mol of phosphine is liberated per mol of catalyst precursor utilized in reaction A).[28] This phosphine would compete for the coordinatively unsaturated $(Ph_3P)_2Ni(butyl)X$ species that could produce C_8 products by coordination and insertion of butene followed by elimination of olefin.

Acknowledgment. This research was supported by the National Science Foundation. An inert atmosphere box used in part of the work was purchased with an equipment grant from Research Corporation.

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Stannylation/Destannylation. Preparation of α-Alkoxy Organolithium Reagents and Synthesis of Dendrolasin via a Carbinyl Carbanion Equivalent

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Abstract: Tributylstannyllithium (I) is a valuable reagent for the preparation of oxyfunctional organolithium reagents and is readily prepared by deprotonation of tributyltin hydride with lithium diisopropylamide. Addition of I to an alkyl or aryl aldehyde yields an α-hydroxystannane ($RCH(OH)Sn(Bu)_3$) which is then protected with α-chloroethyl ethyl ether to give the ethoxyethyl derivative (II) in >90% yield. On treatment with butyllithium, II yields the corresponding α-alkoxy organolithium reagent ($RCH(OR')Li$). These reagents are synthetically useful as carbinyl carbanion equivalents. Application of the new organolithium reagents to natural product synthesis is illustrated by a simple synthesis of dendrolasin and (±)-9-hydroxydendrolasin from furan-3-carboxaldehyde.

Addition reactions in which a carbonyl group behaves like a hydroxyl-substituted carbocation i characterize some of the most widely used synthetic methods for carbon–carbon bond formation. In contrast, only a few synthetic operations based on the opposite charge affinity pattern are known. The main problem with the latter approach centers on the relative un-

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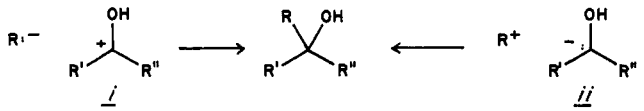
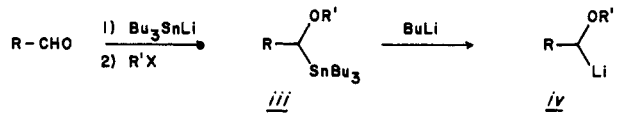
availability of reagents equivalent to the carbinyl carbanion ii. Although metalated organoboranes[2] have been used previously as substitutes for ii, α-alkoxy organolithium reagents seem to promise a more straightforward solution to the problem. The simplest members of this class of compounds, alkoxy methyllithiums, have been known for many years and are usually prepared by halide–lithium or tin–lithium exchange.[3] In contrast, alkyl-substituted α-alkoxy organolithium reagents iv have not been described.[4] Since a general preparation of masked carbinyl carbanions would be quite useful in organic synthesis, we have examined a route to iv starting from an aldehyde and proceeding via an α-alkoxy organostannane.



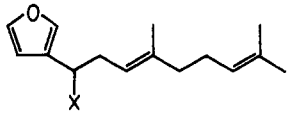
i *ii*

Scheme



iii *iv*

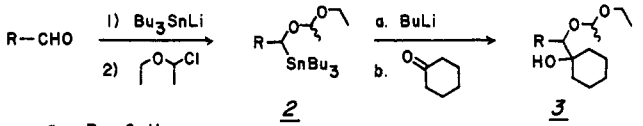
The strategy here is related to some of those used previously for preparation of simple alkoxy methyllithiums (iv, R = H). However, two potential obstacles might be expected to stand between the starting aldehyde and the target organolithium reagent. First, additions of organotin nucleophiles to carbonyl compounds have been reported to proceed in yields of only 40–60%.[6] Second, anion-destabilizing alkyl substituents (R) might be expected to bias the desired equilibrium between iii and iv in favor of iii. In this paper we report that alkyl- and aryl-substituted α-alkoxy organolithium reagents iv are in fact readily available in high overall yields from the corresponding aldehydes. These new reagents may incorporate a variety of conventional hydroxyl protecting groups and are synthetically useful as carbinyl carbanion equivalents. An application of the new methodology to a sterospecific synthesis of dendrolasin[7] (**1a**) and 9-hydroxydendrolasin (**1b**) illustrates some of the potential of these new reagents.



1a X = H
b X = OH

As shown in the scheme, the general approach involves an initial addition of a trialkyltin nucleophile to an aldehyde carbonyl group. Although this operation is a known reaction, it was reported[6] that strong Lewis acid counterions were necessary for simple addition and even then the yields of stannylcarbinols were only moderate. Since we felt that some of these previous problems might be due to inefficiencies in preparation of the trialkyltin nucleophile, we reinvestigated the addition using tetrahydrofuran solutions of tributylstannyllithium (Bu_3SnLi) of known purity. These solutions were prepared by either of two different methods. Aprotic solutions of tributylstannyllithium were prepared as described previously by the addition of buyllithium or methyllithium to hexabutylditin in tetrahydrofuran (0 °C, 15 min).[8] Although the procedure is a simple and efficient one, it suffers somewhat from the expense of hexabutylditin and from the necessity of separating tetrabutyltin (or tributylmethyltin) from the product by chromatography or distillation.[9] We therefore sought a more convenient technique based on the deprotonation of tributyltin hydride.[10] Lithium diisopropylamide in tetrahydrofuran turned out to be an excellent base for this purpose and gave tributylstannyllithium in virtually quantitative yield in minutes at 0 °C. Alkyllithiums and Grignard reagents were less effective. As anticipated tetrahydrofuran solutions of tributylstannyllithium did react with aldehydes at −78 °C to give high yields of tributylstannylcarbinols (iii, R = H). These adducts were found to be rather labile materials which could be chromatographed but which decomposed on contact with acid or on prolonged standing. For this reason, crude adducts were immediately converted to hydroxyl-protected derivatives. Although a variety of standard base-stable alcohol protecting groups could be employed, the ethoxyethyl moiety was found to be particularly convenient and was smoothly introduced by treatment of iii (R = H) with a α-chloroethyl ethyl ether[11] in the presence of *N*,*N*-dimethylaniline (CH_2Cl_2, 0 °C, 10–60 min). It should be pointed out that this procedure for the protection of acid-sensitive alcohols is an extremely mild and general one allowing derivatization of primary, secondary, and many tertiary alcohols. In the case at hand, more common protection procedures using ethyl vinyl ether or dihydropyran failed owing to the extreme acid sensitivity of iii (R′ = H). As shown below, the overall procedure is a particularly efficient one for alkyl and aryl aldehydes, routinely giving α-alkoxystannanes in yields of greater than 90%.

For most preparations of α-alkoxystannanes we used solutions of tributylstannyllithium prepared by deprotonation of tributyltin hydride. For example, 1.1 equiv of lithium diisopropylamide in tetrahydrofuran was prepared in the usual way and was treated with approximately 1.1 equiv of tributyltin hydride at 0 °C (15 min). The resulting light yellow solution of tributylstannyllithium was then chilled to −78 °C and heptanal (1.0 equiv) was added. The reaction appeared complete by TLC as soon as the addition was finished and workup in petroleum ether gave the corresponding stannylcarbinol as the only product. Infrared examination of the isolated reaction product showed a strong hydroxyl stretch of 3400 cm^{-1} and NMR displayed the carbinol proton as a triplet (J = 6.5 Hz) at δ 3.9. Conversion to the *O*-ethoxyethyl derivative was effected with α-chloroethyl ether ($PhNMe_2$, CH_2Cl_2, 0 °C, 1 h). The product α-alkoxystannane **2a** was homogeneous by TLC and was obtained in 97% yield. Application of the sequence to cyclohexanecarboxaldehyde gave the analogous cyclohexyl-substituted α-alkoxystannane **2b** in 95% yield.



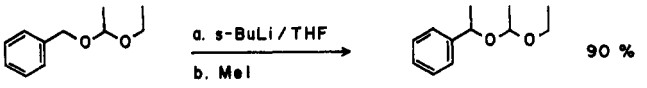
a R = C_6H_{13}
b R = C_6H_{11}

Unlike the intermediate α-hydroxystannanes, O-protected stannanes like **2** are quite stable and may be distilled, chromatographed, or stored for many months under nitrogen or argon.

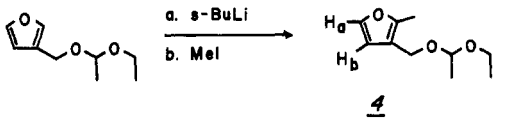
In spite of the anion-destabilizing effect of the alkyl substituent R, addition of *n*-butyllithium to **2** in tetrahydrofuran at −78 °C caused rapid (<1 min) tin/lithium exchange to yield the corresponding α-alkoxy organolithium reagents **2** ($SnBu_3$ = Li). Reaction with cyclohexanone gave the expected products **3a** and **3b** in 81 and 80% yields after short-column chromatography. In the case of **3a**, the 1:1 mixture of diastereomers was separated, and the individual stereoisomeric acetals were characterized and then hydrolyzed to yield the same diol. Significantly, no 1-butylcyclohexanol could be detected in either of the crude products by VPC. This observation is somewhat surprising since it implies that the tin/lithium exchange is virtually complete and leads to what might have been considered to be the less stable organolithium reagent (vide infra). No products resulting from Wittig rearrangement were detected in any of these experiments.

Although aryl aldehydes may also be converted to the corresponding α-aryl α-alkoxy organolithium reagents by a

similar procedure, it is often more convenient to deprotonate a benzylic ether with *sec*-butyllithium (THF, −78 °C, 15 min).[4] Thus *O*-ethoxyethyl benzyl alcohol was metalated and alkylated at the benzylic position in high yield.

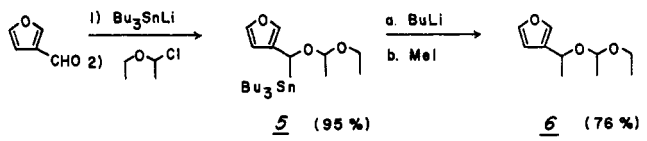


With some compounds, however, the milder organotin procedure is preferable. For example, attempted deprotonation of *O*-ethoxyethylfuran-3-methanol led largely to ring metalation. Interestingly, the metalation appears to have been directed by the ethoxyethyl moiety, as the alkylated product **4** showed NMR coupling of the two furan protons with $J_{a,b}$ = 2 Hz.[12] Preparation of the side-chain-metalated furan was



4

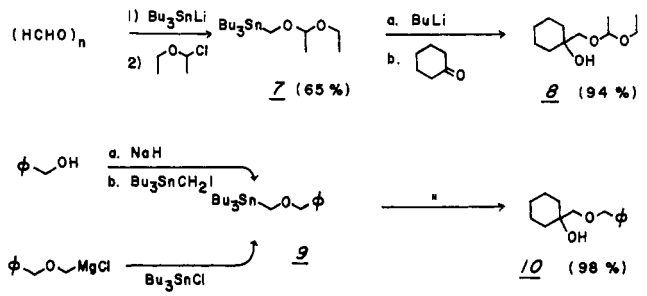
readily accomplished via the alkoxystannane **5**. Butyllithium



5 (95 %) **6** (76 %)

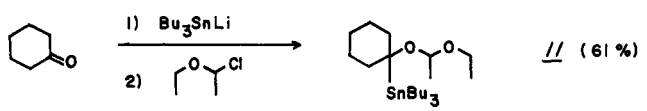
exchange followed by methyl iodide alkylation gave the expected side-chain-methylated furan **6.** This material was not contaminated by **4** and was identified spectrally and by comparison with an authentic sample prepared from furan-3-carboxaldehyde and methyllithium.

Simple unsubstituted α-alkoxy organolithiums are of course also readily prepared from the corresponding α-alkoxystannanes. Thus addition of tributylstannyllithium to paraformaldehyde followed by protection with α-chloroethyl ether gave the *O*-ethoxyethyl compound **7** in 65% yield. Tin/lithium exchange proceeded smoothly and reaction with cyclohexanone produced the monoprotected diol **8** in 94% chromatographed yield. Preparation of the benzyloxy organostannane **9** illus-



trates several other methods for the construction of α-alkoxystannanes. Thus **9** may be prepared by addition of the sodium salt of benzyl alcohol to tributylstannylmethyl iodide[13] or by the addition of benzyloxymethyl Grignard to tributyltin chloride. As reported previously,[3] **9** underwent ready conversion to benzyloxymethyllithium. Reaction with cyclohexanone produced **10** in 98% yield.

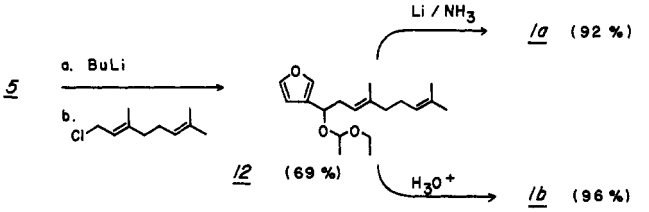
We have been unable to extend the method as far as the generation of tertiary organolithium reagents from saturated ketones. Although tertiary α-alkoxystannanes like **11** were



11 (61 %)

easily prepared in the usual way, attempted butyllithium exchange (THF, −78 °C) and quenching by cyclohexanone led only to 1-butylcyclohexanol and starting α-alkoxystannane. It is not clear whether the absence of exchange products reflects the expected decrease in the stability of the more highly substituted α-alkoxy organolithium or whether the result has a purely kinetic basis.

In order to demonstrate the synthetic potential of these new reagents, we have used the methods described above to effect a simple synthesis of dendrolasin[7] (**1a**) and 9-hydroxydendrolasin (**1b**). The α-alkoxystannane **5** was prepared in 95%



yield from furan-3-carboxladehyde as outlined above. Transmetalation with *n*-butyllithium (1:1 THF/glyme, −78 °C, 1 min) followed by alkylation of the resulting α-alkoxy organolithium reagent with geranyl chloride[14] (1.2 equiv, −78 °C, 1 h) gave **12** in 69% yield after short column chromatography. This approach has a distinct stereochemical advantage over the reverse polarity construction in which an allylic carbanion is added to furan-3-carboxaldehyde. Whereas an allyl organometallic may undergo isomerization, the carbinyl carbanion approach described here assures that the geometry of the central trisubstituted double bond is unambiguously retained.[15] Reduction of **12** with lithium (8 g-atoms) in THF/ammonia (−33 °C, 5 min) gave **1a** as the only product.[16] Hydrolysis (2:2:1 HOAc/MeOH/H_2O, 25 °C, 2.5 h) of **12** gave (±)-9-hydroxydendrolasin (**1b**) in 96% yield.

Since organotin/organolithium exchange reactions appear to be equilibrium processes,[17] it is interesting that the exchange of lithium for tin with α-alkoxystannanes like **2** is 98+% complete at −70 °C. Thus the products in the equilibrium below must be *at least* 2 kcal more stable than the starting materials if quenching by cyclohexanone is fast relative to tin/lithium exchange.

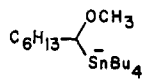
$$\text{BuLi} + \text{RCH(OR')SnBu}_3 \rightleftharpoons \text{Bu}_4\text{Sn} + \text{RCH(OR')Li} \quad (1)$$

Competition experiments conducted to 50% completion offer support to this hypothesis. Dropwise addition of 0.5 equiv of *n*-butyllithium to a vigorously stirred 1:1 mixture of cyclohexanone and α-alkoxystannane in tetrahydrofuran at −78 °C gave mainly 1-butylcyclohexanone. Furthermore, slow addition of 0.5 equiv of cyclohexanone to a 2:1 mixture of butyllithium and α-alkoxystannone (presumably a 1:1 mixture of butyllithium and α-alkoxy organolithium) gave a roughly 1:1 mixture of 1-butylcyclohexanol and 1-alkoxyalkylcyclohexanol. These experiments show that the reaction of butyllithium with cyclohexanone is at least ten times faster than transmetalation and suggest that *n*-butyllithium and α-alkoxy organolithium reagents react with cyclohexanone at comparable rates.

It is tempting, though not strictly proper, to rationalize the position of the equilibrium in terms of the stabilities of the organolithium reagents involved. Although it might be expected that intramolecular chelation by the ethoxyethyl protectin group might stabilize organolithium reagents like **1b** relative to *n*-butyllithium, we find that the α-methoxystannane

14 also gives at least 98% exchange with *n*-butyllithium at −70 °C. Other important factors affecting α-alkoxy organolithium stabilization may include intermolecular (aggregate) chelation and inductive effects of the type suggested previously for sp^3-hybridized oxygen-substituted carbanions.[18]

An alternative explanation of the observed tin/lithium exchange result involves an intermediate tin ate complex **15.** It is conceivable that such a complex could be more stable than tetraalkyltin and alkyllithium and that the complex might preferentially transfer an α-alkoxyalkyl ligand to an electrophile (e.g., cyclohexanone). In order to test for such a mechanism, the following competition experiment was conducted. A 2:1:1 mixture of butyllithium/tetrabutyltin/**14** (hypothetically a 1:1 mixture of ate complexes **15** and **16**) was prepared



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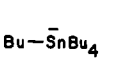

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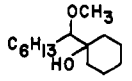

17

at −78 °C and treated with 0.5 equiv of cyclohexanone. *Assuming* that transfer of a butyl ligand to cyclohexanone from either complex **15** or **16** occurs at the same rate, then the competition experiment should yield largely **17** if the ate-complex mechanism is operative. If, on the other hand, product control is governed by the position of the alkyllithium equilibrium, then the experiment should produce a roughly 1:1 mixture of 1-butylcyclohexanol and **17.** Since the latter result is the one that actually obtains, we favor the explanation based on an equilibrium of the type shown in eq 1 which lies far to the right.

Experimental Section

Infrared spectra (IR) were recorded on a Perkin-Elmer Model 427 infrared spectrophotometer and nuclear magnetic resonance (NMR) spectra were determined on a Japan Electron Optics Laboratory Model JMH-100 spectrometer at 100 MHz. Chemical shifts are reported in parts per million (δ) downfield from internal tetramethylsilane. Microanalyses were performed by Galbraith Laboratories, Inc., Knoxville, Tenn. Thin layer chromatograms (TLC) were run on E. Merck glass plates precoated with silica gel 60 F-254 and visualized with a chromic acid spray. Column chromatographic separations were effected on E. Merck silica gel G using a modified short column technique. Tetrahydrofuran and 1,2-dimethoxyethane were distilled under nitrogen from sodium benzophenone ketyl and diisopropylamine was distilled from calcium hydride. Petroleum ether refers to that hydrocarbon fraction boiling at 35–50 °C. Hexabutylditin (lot 011873) and butyllithium were purchased from Alfa Inorganics and tributyltin hydride was prepared from tributyltin chloride and stored under argon.

Tributylstannyllithium. A. Preparation from Hexabutylditin. A solution of hexabutylditin (3.14 g, 5.4 mmol, 2.8 mL) in anhydrous tetrahydrofuran (10 mL) under nitrogen was cooled to 0 °. The solution was stirred while *n*-butyllithium (2 mL of a 2.5 M hexane solution, 5 mmol) was added. The reaction was complete within 15 min at 0 °C and gave a pale yellow solution which was ca. 0.34 M in Bu_4Sn and Bu_3SnLi.

B. Preparation from Tributyltin Hydride. Anhydrous tetrahydrofuran (10 mL) and diisopropylamine (0.8 mL) were stirred under nitrogen at 0 °C while *n*-butyllithium (2 mL of a 2.5 M hexane solution, 5 mmol) was added dropwise. The resulting solution was stirred for an additional 5 min and tributyltin hydride (1.45 g, 1.32 mL, 5 mmol) was added via syringe. After ca. 15 min at 0 °C the reaction was complete.

General Procedure. Preparation of α-Alkoxy Organostannanes from Aldehydes and Ketones. A solution of Bu_3SnLi (10 mmol) was prepared under nitrogen from tributyltin hydride and lithium diisopropylamide as described above (procedure B) and chilled to −78 °C. A solution of the aldehyde or ketone (10 mmol) in ca. 2 mL of anhydrous tetrahydrofuran was then added dropwise with stirring (ca. 1 min). After stirring for an additional 5 min, the cold reaction mixture was quenched with dilute ammonium chloride and partitioned between petroleum ether and water. The organic phase was dried over sodium sulfate and the solvent was removed at reduced pressure (temperature <30 °C). The product α-hydroxy organostannane was immediately converted to the *O*-ethoxyethyl derivative as described below.

The crude product was dissolved in 25 mL of methylene chloride containing 2.5 mL of *N,N*-dimethylaniline and cooled to 0 °C under a drying tube. The solution was stirred and α-chloroethyl ethyl ether (1.7 mL, 15 mmol) was added. After 1 h, the reaction mixture was poured into 100 mL of petroleum ether and washed successively with ice-cold 0.5 N aqueous hydrochloric acid (2 × 50 mL), water (50 mL), and saturated aqueous sodium bicarbonate (50 mL). The organic phase was dried over sodium sulfate. The solvent was finally evaporated at reduced pressure and the residue was pumped down under high vacuum to yield the ethoxyethyl-protected α-alkoxy organostannane.

α-Alkoxy Organostannane 2a from Heptanal. Use of the general procedure with heptanal (1.14 g, 1.34 mL, 10 mmol) gave **2a** (4.6 g, 97%). The material was essentially homogeneous by TLC and was used without purification for preparation of the corresponding organolithium reagent. Analytically pure material was obtained by short-column chromatography on silica gel G with 0.5% ethyl acetate/petroleum ether: TLC (2% ethyl acetate/petroleum ether) R_f 0.50; IR (neat) 1460, 1375, 1120, 1090, 860 cm^{-1}; NMR (δ^{CCl_4}) 4.34 (1 H, m), 3.84 (1 H, m), 3.31 (2 H, br q, J = 7 Hz), 0.8–1.9 (46 H, m).

Anal. ($C_{23}H_{50}O_2Sn$) C, H.

α-Alkoxy Organostannane 2b from Cyclohexanecarboxaldehyde. Use of the general procedure with cyclohexanecarboxaldehyde (1.12 g, 1.22 mL, 10 mmol) gave **2b** (4.5 g, 95%). As found with the adduct from heptanal, crude **2b** was also obtained in a state of high purity as judged by TLC. Analytically pure material was prepared by short-column chromatography (silica gel G, 0.5% ethyl acetate/petroleum ether): TLC (2% ethyl acetate/petroleum ether) R_f 0.42–0.52; IR (neat) 1450, 1380, 1120, 1090, 1055, 995, 980, 860 cm^{-1}; NMR (δ^{CCl_4}) 4.37 (1 H, m), 3.80 (1 H, m), 3.36 (2 H, m), 0.8–1.9 (44 H, m).

Anal. ($C_{23}H_{48}O_2Sn$) C, H.

α-Alkoxy Organostannane 5 from Furan-3-carboxaldehyde. Use of the general procedure with freshly distilled furan-3-carboxaldehyde (prepared by oxidation of furan-3-methanol with pyridinium chlorochromate) (0.96 g, 10 mmol) gave **5** (4.3 g, 95%) which was essentially homogeneous by TLC: TLC (2% ethyl acetate/petroleum ether) R_f 0.44; IR (neat) 1500, 1460, 1380, 1165, 1150, 1080, 1060, 1025, 1000, 960, 925, 870, 775; 745 cm^{-1}; NMR (δ^{CCl_4}) 7.10 (1 H, br s), 6.95 (1 H, br s), 6.05 (1 H, m), 4.84 (0.5 H, s), 4.68 (0.5 H, s), 4.45 (1 H, br q, J = 5 Hz), 3.1–3.6 (2 H, m), 0.75–1.60 (33 H, m).

Anal. ($C_{22}H_{40}O_3Sn$) C, H.

α-Alkoxy Organostannane 11 from Cyclohexanone. Use of the general procedure with cyclohexanone (0.98 g, 10 mmol) gave crude product (4.68 g) which contained a substantial amount of very high R_f material. Short-column chromatography of a 1.17-g portion of the crude product on 50 g of silica gel G with 0.5% ethyl actate/petroleum ether gave pure **11** (0.70 g, 61%): TLC (1% ethyl acetate/petroleum ether) R_f 0.27: IR (neat) 1455, 1445, 1375, 1155, 1135, 1120, 1090, 1055, 1030, 970, 925, 870 cm^{-1}; NMR (δ^{CCl_4}) 4.76 (1 H, q, J = 5 Hz), 3.43 (2 H, q, J = 7 Hz), 0.75–2.0 (43 H, m).

Anal. ($C_{22}H_{46}O_2Sn$) C, H.

General Procedure. Preparation of α-Alkoxy Organolithiums from α-Alkoxy Organostannanes. A solution of the α-alkoxy organostannane (1.25 mmol) in 5 mL of anhydrous tetrahydrofuran was cooled to −78 °C under nitrogen. The solution was stirred while *n*-butyllithium (0.48 mL of a 2.5 M hexane solution, 1.20 mmol) was added. Within 5 min, the exchange was complete and cyclohexanone (98 mg, 1 mmol) or other electrophile was added. After 10 min, the cold reaction mixture was partitioned between water and petroleum ether. The organic phase was dried (sodium sulfate) and the solvent was evaporated. Short-column chromatography served to separate the desired product from contaminating Bu_4Sn and any other impurities.

***O*-Ethoxyethyl Diol 3a from 2a.** α-Alkoxystannane **2a** (596 mg, 1.25 mmol) was processed as described in the general procedure above. The crude product weighed 784 mg. Its TLC (10% ethyl acetate/petroleum ether) showed two major spots (R_f 0.48 and 0.58) and a minor spot (R_f 0.71) in addition to Bu_4Sn. The two major compounds were separated and isolated by short column chromatography (12 g of silica gel G, 5% ethyl acetate/petroleum ether). These compounds were identified as the expected 1:1 mixture of epimeric actals **3a** and **3b** which weighed 233 mg (81%).

Epimer A, **3a** (R_f 0.58): IR (neat) 3450, 1445, 1390, 1375, 1320, 1255, 1130, 1115, 1090, 1050, 1030, 980, 840 cm^{-1}; NMR (δ^{CCl_4}) 4.41 (1 H, q, J = 5 Hz), 3.42 (2 H, q, J = 7 Hz), 3.25 (1 H, s, -OH), 3.06 (1 H, m), 0.80–1.90 (29 H, m). Bulb-to-bulb distillation (0.05 mm, oven 105 °C) gave the analytical sample.

Anal. ($C_{17}H_{34}O_3$) C, H.

Epimer B, **3a** (R_f 0.48): IR (neat) 3450, 1445, 1390, 1380, 1340, 1325, 1255, 1130, 1100, 1055, 1040, 1030, 980, 840 cm^{-1}; NMR (δ^{CCl_4}) 4.57 (1 H, q, J = 5 Hz), 3.42 (2 H, m), 3.08 (1 H, m), 2.00 (1 H, s, -OH), 0.75-1.90 (29 H, m). Bulb-to-bulb distillation (0.05 mm, oven 105 °C) gave the analytical sample.

Anal. ($C_{17}H_{34}O_3$) C, H.

The identity of the two compounds as epimeric acetals was confirmed by hydrolysis (0.1 N aqueous hydrochloric acid/methanol) of the two compounds to the same diol.

***O*-Ethoxyethyl Diol 3b from 2b.** α-Alkoxystannane **2b** (594 mg, 1.25 mmol) was processed as described in the general procedure above. The crude product weighed 765 mg and its TLC (10% ethyl acetate/petroleum ether) showed two major spots (R_f 0.50 and 0.55) and a minor spot (R_f 0.62). The two major compounds were isolated by short-column chromatography (14 g of silica gel G, 5% ethyl acetate/petroleum ether) as a colorless syrup (228 mg, 80%): IR (neat) 3470, 1450, 1390, 1380, 1345, 1325, 1250, 1150, 1095, 1085, 1075, 1060, 1000, 980, 940, 840 cm^{-1}; NMR (δ^{CCl_4}) 4.43 (1 H, m), 3.40 (2 H, br q, J = 7 Hz), 2.95 (1 H, m), 1.00-1.90 (28 H, m). Bulb-to-bulb distillation gave the analytical sample (0.05 mm, oven 105-110 °C).

Anal. ($C_{17}H_{32}O_3$) C, H.

***O*-Ethoxyethyl α-Methylbenzyl Alcohol.** *O*-Ethoxyethyl benzyl alcohol (180 mg, 1 mmol) was dissolved in 5 mL of anhydrous tetrahydrofuran and cooled to −78 °C under nitrogen. A pentane solution of *sec*-butyllithium (1.2 mmol) was added and the resulting bright orange solution was stirred for 10 min. Addition of 0.2 mL of methyl iodide immediately discharged the color. The reaction mixture was poured into petroleum ether and washed with water. Drying (sodium sulfate) and solvent removal gave a pale yellow oil (212 mg). Bulb-to-bulb distillation (1 mm) gave 176 mg (90%) of material which was shown to be the *O*-ethoxyethyl derivative of α-methylbenzyl alcohol by IR, NMR, and TLC comparison with an authentic sample.

***O*-Ethoxyethyl 2-Methylfuran-3-methanol (4).** The *O*-ethoxyethyl derivative of furan-3-methanol (170 mg, 1 mmol) was treated with *sec*-butyllithium and methyl iodide as described in the preparation above. The product was a yellow oil weighing 204 mg: TLC (10% ethyl acetate/petroleum ether) showed only one spot (R_f 0.71); NMR (δ^{CCl_4}); 7.02 (1 H, br d, J = 2 Hz), 6.10 (1 H, br d, J = 2 Hz), 4.51 (1 H, br q, J = 5 Hz), 4.15 (2 H, br s), 3.36 (2 H, m), 2.18 (3 H, s), 1.18 (3 H, d, J = 5 Hz), 1.11 (3 H, t, J = 7 Hz).

***O*-Ethoxyethyl α-Methylfuran-3-methanol (6).** α-Alkoxy organostannane **5** (230 mg, 0.50 mmol) was dissolved in 2.5 mL of anhydrous tetrahydrofuran and chilled to −78 °C under nitrogen. *n*-Butyllithium (0.2 mL of a 2.5 M hexane solution, 0.50 mmol) was added and the resulting mixture was stirred for 30 s. Methyl iodide (0.2 mL) was then added and the reaction mixture was poured into petroleum ether. After washing with water and drying (sodium sulfate), solvent removal gave a colorless oil (300 mg). TLC (5% ethyl actate/petroleum ether) showed a single major spot (R_f 0.44) and several very minor spots in addition to Bu_4Sn. Short-column chromatography (13 g of silica gel G, 3% ethyl acetate/petroleum ether) allowed isolation of the major product **6** (70 mg, 76%): IR (neat) 3140, 3000, 2950, 2900, 1590, 1500, 1445, 1380, 1330, 1160, 1130, 1085, 1060, 1030, 1005, 975, 940, 875, 790, 730 cm^{-1}; NMR (δ^{CCl_4}) 7.14 (2 H, br s), 6.20 (1 H, s), 4.52 (2 H, m), 3.30 (2 H, m), 1.33 (3 H, dd, J = 1, 7 Hz), 1.18 (3 H, d, J = 7 Hz), 1.06 (3 H, t, J = 5 Hz).

Structure was confirmed by comparison with an authentic sample by IR, NMR, and TLC.

(Ethoxyethyloxymethyl)tributylstannane (7). To a tetrahydrofuran solution of Bu_3SnLi (50 mmol) prepared by method B above was added paraformaldehyde (1.5 g, 50 mmol) at room temperature. After stirring for 3 h under nitrogen, the reaction mixture was poured into petroleum ether (300 mL) and was washed with water (2 × 200 mL). The organic phase was dried, concentrated, and applied to a 2-in. diameter chromatography column containing 70 g of silica gel G packed with hexane. Elution with hexane removed residual nonpolar butyltin compounds. The product Bu_3SnCH_2OH was then obtained by elution with 10% ethyl acetate in hexane. The hydroxymethylstannane was isolated as a coloress oil which gradually decomposed on standing, TLC (5% ethyl acetate/pentane) R_f 0.31. For this reason, Bu_3SnCH_2OH should be protected as described below immediately after isolation.

Protection as a mixed acetal was effected by dissolving the freshly prepared Bu_3SnCH_2OH in 100-mL of methylene chloride containing *N*,*N*-dimethylaniline (7.2 g, 7.7 mL, 60 mmol). The solution was stirred at 0 °C and α-chloroethyl ethyl ether (5.42 g, 5.6 mL, 50 mmol) was added in a single portion. After 5 min, the reaction mixture was poured into 300 mL of petroleum ether and was washed successively with ice-cold 0.5 N aqueous hydrochloric acid (2 × 100 mL), water (100 mL), and saturated aqueous sodium bicarbonate (100 mL). Drying over sodium sulfate and solvent removal gave pure **7** as a colorless oil (12.8 g, 65%): TLC (5% ethyl acetate/pentane) R_f 0.54; IR (neat) 1460, 1380, 1120, 1080, 1060, 1030, 1020, 970, 865 cm^{-1}; NMR (δ^{CCl_4}) 4.35 (1 H, q, J = 6 Hz), 3.50 (2 H, AB_q, J = 10 Hz, $\Delta\nu_{AB}$ = 18 Hz), 3.30 (2 H, m), 0.75-1.8 (33 H, m).

Anal. ($C_{17}H_{38}O_2Sn$) C, H.

***O*-Ethoxyethyl Diol 8 from 7.** α-Alkoxystannane **7** (491 mg, 1.25 mmol) was submitted to the general procedure above except that the reaction mixture was worked up in ether and washed only with brine. The crude product weighed 642 mg and its TLC showed only one spot (50% ethyl acetate/petroleum ether, R_f 0.58) in addition to Bu_4Sn. Short-column chromatography (12 g of silica gel G, 10% ethyl acetate/petroleum ether) gave pure **8** as a colorless syrup (190 mg, 94%): IR (neat) 3470, 1450, 1380, 1340, 1140, 1100, 1060, 1000, 965, 950, 920, 870 cm^{-1}; NMR (δ^{CCl_4}) 4.57 (1 H, q, J = 5 Hz), 3.65 (2 H, m), 3.18 (2 H, AB_q, J = 10 Hz, $\Delta\nu_{AB}$ = 14 Hz), 2.10 (1 H, s, -OH), 1.0-1.8 (10 H, m), 1.24 (3 H, d, J = 5 Hz), 1.15 (3 H, t, J = 7 Hz).

Anal. ($C_{11}H_{22}O_3$) C, H.

(Benzyloxymethyl)tributylstannane (9). A solution of 0.15 mol of ICH_2ZnI in 100 mL of tetrahydrofuran was prepared as described by Seyferth and Andrews,[13] and then treated with tributyltin chloride (32.5 g, 27 mL, 0.1 mol). After stirring under nitrogen for 18 h, the reaction mixture was poured into 300 mL of petroleum ether and was washed with water (2 × 200 mL). After drying over anhydrous sodium sulfate, the solvent was removed at reduced pressure to yield Bu_3SnCH_2I as a stable, colorless oil (41.5 g, 96%) (bp 100-110 °C (0.01 mm)).

Sodium hydride (50% dispersion, 4.8 g, 0.10 mol) was washed with pentane (three times) and suspended in 250 mL of anhydrous tetrahydrofuran under nitrogen. Benzyl alcohol (9.18 g, 0.085 mol) was added dropwise with stirring. Stirring was continued at room temperature for ca. 1 h past the time when gas evolution ceased and then Bu_3SnCH_2I (28 g, 19.5 mL, 0.065 mol) was added. The mixture was stirred for 48 h and was then treated with a little methanol to destroy any excess sodium hydride. The reaction mixture was finally poured into 1 L of petroleum ether, washed with water (2 × 250 mL), and dried over sodium sulfate. Solvent removal at reduced pressure followed by vacuum distillation through a 20-in. Vigreux column gave **9** (bp 140-144 °C (0.03 mm)) (21.8 g, 81%): TLC (10% ethyl acetate/pentane) R_f 0.78; IR (neat) 1455, 1375, 1085, 1065, 730, 695 cm^{-1}; (δ^{CCl_4}) 7.15 (5 H, s), 4.40 (2 H, s).

Anal. ($C_{20}H_{36}OSn$) C, H.

***O*-Benzyl Diol 10 from 9.** α-Alkoxystannane **9** (514 mg, 1.25 mmol) was exchanged with butyllithium and reacted with cyclohexanone as described in the general procedure above. The crude product weighed 677 mg and its TLC showed only one spot (5% ethyl acetate/petroleum ether, R_f 0.16) in addition to Bu_4Sn. Short-column chromatography (10 g of silica gel G, 7.5% ethyl acetate/petroleum ether) allowed isolation of the pure product (**10**) as a colorless oil (216 mg, 98%). The analytical sample was obtained by bulb-to-bulb distillation (0.1 mm, oven 110 °C): IR (neat) 3450, 1500, 1455, 1360, 1100, 975, 920, 740, 700 cm^{-1}; NMR (δ^{CCl_4}) 7.15 (5 H, s), 4.55 (2 H, s), 3.25 (2 H, s), 1.92 (1 H, s, -OH), 1.1-1.8 (10 H, m).

Anal. ($C_{14}H_{20}O_2$) C, H.

Attempted Exchange with α-Alkoxy Organostannane 11. α-Alkoxystannane **11** (461 mg, 1 mmol) was dissolved in 5 mL of anhydrous tetrahydrofuran, chilled to − 78 °C under nitrogen, and treated with 0.80 mmol of *n*-butyllithium. After stirring for 5 min, the reaction was quenched with cyclohexanone (98 mg, 1 mmol). The mixture was poured into petroleum ether, washed with water, and dried over sodium sulfate. Solvent removal gave a colorless oil (575 mg). TLC and VPC analysis (5% ethyl acetate/petroleum ether) showed only starting **11** and 1-butylcyclohexanol.

***O*-Ethoxyethyl 9-Hydroxydendrolasin (12).** A mixture of anhydrous tetrahydrofuran (3 mL) and 1,2-dimethoxyethane (3 mL) was chilled to −78 °C under nitrogen. *n*-Butyllithium (1 mL of 2.5 M hexane solution, 2.5 mmol) was added. The mixture was stirred while α-alkoxystannane **5** (918 mg, 2 mmol) in 2 mL of anhydrous tetrahydrofuran was added dropwise. After ca. 1 min, geranyl chloride[14]

(freshly filtered (rapidly) through a 1-in. Florisil column with cold pentane) (431 mg, 2.5 mmol) was injected. The mixture was stirred for 1 h at −78 °C and was poured into 50 mL of petroleum ether. The solution was washed with water (2 × 25 mL), dried (sodium sulfate), and evaporated to yield a light yellow oil (1.41 g). TLC (5% ethyl acetate/petroleum ether) showed a single major spot (R_f 0.44) in addition to several minor spots (R_f 0.31, 0.50, 0.76 (geranyl chloride), and 0.85 (Bu_4Sn)). Short-column chromatography (60 g of silica gel G, 2.5% ethyl acetate/petroleum ether) allowed isolation of the major product as a colorless oil (425 mg, 69%): IR (neat) 1500, 1445, 1380, 1330, 1130, 1098, 1055, 1025, 950, 875, 790 cm^{-1}; NMR (δ^{CCl_4}) 7.27 (2 H, m), 6.32 (1 H, m), 5.06 (2 H, m), 4.35–4.73 (2 H, m), 3.06–3.66 (2 H, m), 2.34 (2 H, m), 1.96 (4 H, br s), 1.65 (3 H, br s), 1.57 (6 H, br s), 0.95–1.20 (6 H, m).

Anal. ($C_{19}H_{30}O_3$) C, H.

Dendrolasin (1a). Anhydrous liquid ammonia (ca. 10 mL) at −33 °C was stirred under argon and lithium (26 mg, 3.66 g-atoms) was added. After stirring for 2.5 min, compound **12** (140 mg, 0.46 mmol) in 2.5 mL of anhydrous tetrahydrofuran was added in a single portion. After 5 min, first isoprene and then ammonium chloride were added to quench the reaction. The ammonia was allowed to evaporate and the residue was taken up in petroleum ether. The solution was dried over sodium sulfate and the solvent was removed to give a colorless oil (110 mg). TLC analysis (5% ethyl acetate/petroleum ether) showed a trace of starting material (R_f 0.45) and a large new spot (R_f 0.67). Short-column chromatography (12 g of silica gel G, 1% ethyl acetate/petroleum ether) gave pure dendrolasin (92 mg, 92%). That material was found to be identical by TLC, IR, and NMR with an authentic sample prepared by another route.[16]

9-Hydroxydendrolasin (1b). Compound **12** (145 mg, 0.47 mmol) was dissolved in a mixture of glacial acetic acid (1 mL), methanol (1 mL), and water (0.5 mL). The mixture was stirred at 25 °C for 2.5 h and was partitioned between petroleum ether and water. The organic phase was washed with saturated aqueous sodium bicarbonate and dried over sodium sulfate. Solvent removal gave a colorless oil (107 mg, 96%) which was homogenous by TLC (10% ethyl acetate/petroleum ether; R_f 0.31) and VPC (6-ft 1.5% OV-101 column, temperature programmed 150 → 200 °C, program rate 10 °C/min, retention time 6.3 min): IR (neat) 3400, 1500, 1445, 1380, 1160, 1025, 875, 790, 730 cm^{-1}; NMR (δ^{CCl_4}) 7.24 (2 H, m), 6.29 (1 H, br s), 6.07 (2 H, m), 4.52 (1 H, t, J = 6 Hz), 2.92 (1 H, s, -OH), 2.37 (2 H, br t, J = 7 Hz), 2.01 (4 H, br s), 1.67 (3 H, br s), 1.60 (6 H, br s).

Anal. ($C_{15}H_{22}O_2$) C, H.

α-Methoxy Organostannane 14. *n*-Heptanal dimethyl acetal (3.2 g, 20 mmol) was dissolved in 10 mL of methylene chloride and treated with acetyl chloride (10 mL). After 3 h NMR monitoring revealed that the reaction was complete. The volatile materials were removed at ~5 mm (25 °C) to yield a light brown oil, 1-chloro-1-methoxyheptane.

A solution of Bu_3SnLi (7.5 mmol) was prepared by method A and cooled to −78 °C. 1-Chloro-1-methoxyheptane (1.3 mL, ca. 7.5 mmol) was added dropwise via syringe with stirring. After 10 min, the mixture was poured into petroleum ether and washed with water. Drying (sodium sulfate) and solvent removal gave the crude product as a yellow oil. TLC analysis (5% ethyl acetate/petroleum ether) showed one major spot (R_f 0.61) in addition to Bu_4Sn. Short-column chromotography (50 g of silica gel G, 2.5% ethyl acetate/petroleum ether) gave pure **14** (2.3 g, 73%): IR (neat) 1460, 1375, 1105, 1080, 870, 860 cm^{-1}; NMR (δ^{CCl_4}) 3.61 (1 H, t, J = 6 Hz), 3.22 (3 H, s), 1.1–1.8 (28 H, m), 0.91 (12 H, br t, J = 6 Hz).

Anal. ($C_{20}H_{44}OSn$) C, H.

Exchange with α-Methoxy Organostannane 14. Compound **14** (210 mg, 0.5 mmol) in 5 mL of anhydrous tetrahydrofuran under nitrogen was cooled to −78 °C. The solution was stirred and *n*-butyllithium (0.16 mL of 2.5 M hexane solution, 0.4 mmol) was added. After 5 min, cyclohexanone (0.05 mL, ~0.5 mmol) was added. After an additonal 5 min, the reaction mixture was quenched with water and partitioned between water and petroleum ether. The organic phase was dried over sodium sulfate and the solvents were removed to yield a colorless oil (283 mg). TLC (silica gel, 10% ethyl acetate/petroleum ether) showed no material corresponding to 1-butylcyclohexanol but did show one spot (R_f 0.45) in addition to Bu_4Sn and a trace of **14.** VPC (6-ft 1.5% OV-101 column, temperature program 150 → 200 °C, program rate 10 °C/min) confirmed the total absence of 1-butylcyclohexanol. The compound having R_f 0.45 was isolated by short column chromatography (10 g of silica gel G, 5% ethyl acetate/petroleum ether) and identified as the methoxy alcohol **17:** IR (neat) 3475, 1450, 1100, 970 cm^{-1}; NMR (δ^{CCl_4}) 3.44 (3 H, s), 2.75 (1 H, m), 1.76 (1 H, s, -OH), 1.00–1.80 (20 H, m), 0.90 (3 H, br t).

Anal. ($C_{14}H_{28}O_2$) C, H.

Competition of α-Alkoxy Organostannane 14 and Cyclohexanone for Butyllithium. A mixture of α-methoxystannane **14** (210 mg. 0.50 mmol) and cyclohexanone (49 mg, 0.50 mmol) in 5 mL of anhydrous tetrahydrofuran was chilled to −78 °C under nitrogen, The mixture was stirred vigorously and *n*-butyllithium (0.10 mL of 2.5 M hexane solution, 0.25 mmol) was added dropwise. After 5 min, the mixture was quenched with water and partitioned between water and petroleum ether. The organic phase was dried (sodium sulfate) and the solvent removed to yield a colorless oil (281 mg). TLC (8% ethyl acetate/petroleum ether) showed only spots corresponding to 1-butylcyclohexanol (R_f 0.34) and starting stannane **14** (R_f 0.94). VPC (6-ft 1.5% OV-101 column, temperature program 150 → 200 °C, program rate 10 °C/min) analysis showed three peaks at times 1.2, 4.6, and 4.9 min having areas 92:2:6, respectively. These peaks corresponded to 1-butylcyclohexanol, methoxy alcohol **17,** and Bu_4Sn. Starting α-methoxystannane **14** did not emerge from the column under these conditions.

Competition of α-Alkoxy Organolithium 14 ($SnBu_3$ = Li) and *n*-Butyllithium for Cyclohexanone. A solution of α-methoxystannane **14** (210 mg, 0.50 mmol) in 5 mL of anhydrous tetrahydrofuran was cooled to −78 °C under nitrogen. *n*-Butyllithium (0.4 mL of a 2.5 M hexane solution, 1.0 mmol) was added and the resulting mixture was stirred for 5 min. The solution was then stirred vigorously and cyclohexanone (25 mL, 0.25 mmol) was added. After an additional 5 min, the mixture was quenched with water and partitioned between water and petroleum ether. The organic phase was dried (sodium sulfate) and evaporated to give a colorless oil (278 mg). TLC (5% ethyl acetate/petroleum ether) showed two major spots (R_f 0.20 and 0.26), corresponding to 1-butylcyclohexanol and methoxy alcohol **17,** in addition to Bu_4Sn. VPC (same conditions as above) showed three peaks at times 1.2, 4.5, and 5.0 min having approximate areas 1:1–2:25. Incomplete resolution of the last two peaks made more accurate area measurement impossible. These three peaks corresponded to 1-butylcyclohexanol, methoxy alcohol **17,** and Bu_4Sn, respectively.

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Conformational Analysis of Tertiary Cycloalkyl (C_6, C_7, C_8) Carbocations. Unexpected Preference for the Twist-Boat Conformation in the Cyclohexyl Case

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Abstract: In carbocations, chair conformations appear to be much less stable than in neutral organic analogues. Thus, tertiary cyclohexyl cations have a twist-boat ground state which is 500 cal/mol more stable than the chair conformation. The equilibrium constant, twist-boat–chair, is slightly solvent dependent, increasing in nonpolar and decreasing in more polar solvents. The tertiary cycloheptyl cation is a fluxionally mobile molecule but the methycyclooctyl cation has an unsymmetrical chair–twist-boat conformation in which the pseudorotational motion can be "frozen out" at low temperatures. The reported 2-methyl-2-bicyclo[3.2.1]octyl cation is instead the 2-methyl-2-bicyclo[2.2.2]octyl cation. At very low temperatures, the former cation can be made but it was not possible to assign a conformation to the six-membered ring. The 9-methyl-9-bicyclo[3.3.1]nonyl cation is postulated to have a chair–boat conformation in contrast to the dichair conformation observed in neutral compounds. Attempts to prepare the observable 2-methyl-2-twistyl cation were unsuccessful.

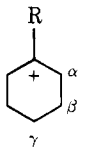
Virtually all simple neutral cyclohexane, cycloheptane, and cyclooctane ring systems have been subjected to some degree of conformational analysis.[1] However, while cycloalkyl cations, particularly cyclohexyl cation, have been well studied as solvolysis intermediates, virtually nothing is known concerning their conformational ground states. The two closest relatives in the cyclohexyl case (one sp^2 center) are cyclohexanone (**1**) and methylenecyclohexane (**2**), both having

1

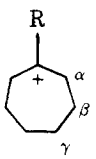
2

ground-state chair conformations.[2]

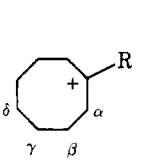
In observable ion studies, it is impossible at present to prepare secondary cycloalkyl cations, except for the cyclopentyl cation. All higher members collapse "immediately" to smaller ring tertiary ions,[3] even at very low temperatures. However, the tertiary cyclohexyl **3**, cycloheptyl **4**, and cyclooctyl **5** cat-



3a, R = CH_3
b, R = *n*-butyl



4, R = CH_3



5, R = CH_3

ions can be easily prepared. Indeed, ion **3a** and many other tertiary cyclohexyl cations have been previously reported.[4]

In this paper, we report NMR spectral evidence from which one can deduce the ground state conformations of **3** and **5** and related spectral evidence giving the $\Delta G^{\ddagger}$ activation barrier for conformer interconversions in **5** (and upper limits for **3** and **4**). These results are then used to examine the conformations of two fused bicyclo systems containing flexible six-membered ring cations.

Results

The Cyclohexyl Case. The ^1H NMR spectrum of the methylcyclohexyl cation **3a** consists of four rather broad lines, assigned to CH_3, αCH_2, βCH_2, and γCH_2.[4a] The spin–spin coupling between these groups is not well resolved so that conventional (Karplus curve) ^1H NMR spectroscopy is not feasible for determining the conformation of **3a**, the spectra merely confirming the gross features of this molecule.

At first sight, ^{13}C NMR spectroscopy looks even less promising since **3a** simply shows, with proton decoupling, the expected five lines (Table I). However, one of these lines, assigned to the β carbons, shows a large chemical shift variation with changes in temperature. This variation is shown graphically in Figure 1, and can be contrasted with the α carbons and the CH_3 carbon, also shown in Figure 1. The chemical shift position of the β carbon also varies with solvent and this is assumed to not be an "intrinsic solvent shift" (see later). Combining variations in temperature and solvent, one is able to "move" the β carbon chemical shift over a range of about 9 ppm. Two near extremes in this regard are shown in Figure 2, together with the experimental conditions used.

The chemical shift vs. temperature behavior of the β carbons in **3a** is very characteristic of an equilibrium situation, involving two or more very rapidly equilibrating structures. In the present case, there is no evidence for any other isomeric ion in rapid equilibrium with **3a**, nor would one expect there to be. One must conclude, therefore, that the equilibrium is between *different conformers of the cyclohexyl ring*. We believe that one conformer is the chair form **6a**, while the other must be from the twist-boat (TB) **6b** or **6c**, or boat (B) **6d** or **6e** pseudorotation family.[2] Of these, the twist-boat conformers **6b** and **6c** are expected to be slightly more stable than the boat conformers.[1]

In fact, the results seem to us to be reasonably consistent with the twist-boat conformer **6b** as the second populated conformer in the very rapid equilibrium with **6a**. This choice of **6a** and **6b** will seem rather arbitrary at this juncture but the evidence accumulates as other systems are examined.

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