Total Synthesis of (+)-Dactylol *via* a Novel [3 + 5] Annulation Approach

Gary A. Molander* and Paul R. Eastwood

Department of Chemistry and Biochemistry, University of Colorado, Boulder, Colorado 80309-0215

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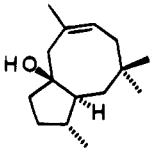
(+)-Dactylol (**1**) has been synthesized from the known (*R*)-3-methyl-2-methylenecyclopentanone (**20**) in six steps. The key step in the synthesis involves a regioselective and stereoselective [3 + 5] annulation to afford a tricyclic ether, which upon suitable functional group manipulation was opened to provide the natural product.

Dactylol (**1**), an unusual cyclooctanoid sesquiterpene, was isolated in 1978 from the Caribbean sea hare, *Aplysia dactylomela*, by Schmitz *et al.*[1] This compound has been the subject of several total syntheses.[2] The reported syntheses have served to illustrate diverse methods to gain entry into eight-membered ring systems, an increasingly important goal that remains a significant challenge in synthetic organic chemistry.[3] Key steps in the previous syntheses of this compound have included an oxy-Cope type rearrangement of a dialkenyl cyclobutanol,[2b] an intramolecular [6π + 2π] photocycloaddition of a trisubstituted tropone[2d] and a biomimetic cyclization from a humulene derivative.[2c] To date, no attempt has been made to synthesize dactylol in nonracemic form. Herein we report a concise, nonracemic synthesis of dactyol utilizing a [3 + 5] annulation method. This approach proceeds by formation of a tricyclic ether intermediate that was ring-opened in the final step to unveil the cyclooctanoid ring system.

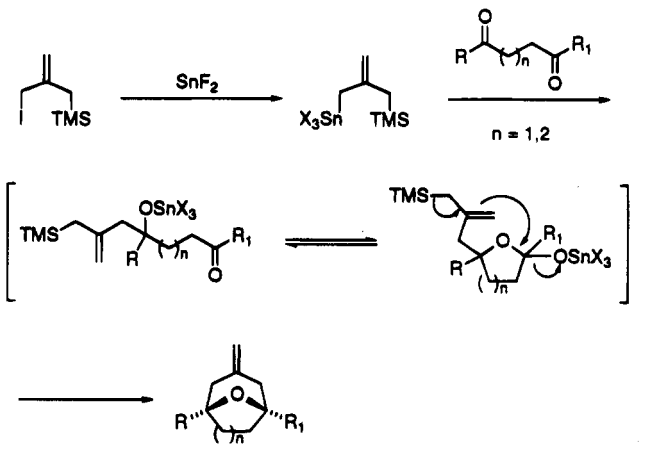


(+)-Dactylol (1)

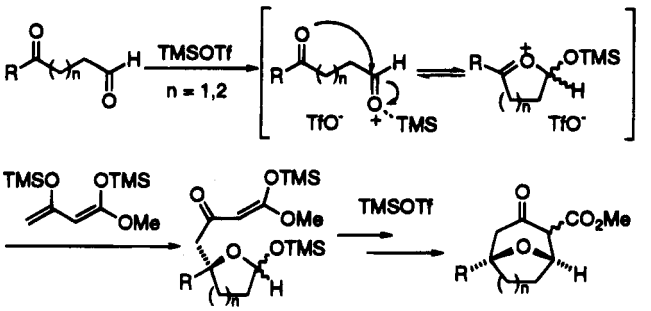
Results and Discussion

For some time we have been interested in [3 + 4] and [3 + 5] annulations in which the normal difficulties encountered in forming seven- and eight-membered rings are overcome by incorporation of suitable control elements. In the first method developed (Scheme 1), a dinucleophilic synthon was generated by the reaction of stannous fluoride with 2-(iodomethyl)-3-(trimethylsilyl)-propene. Reaction of this synthon with 1,4- and 1,5-dicarbonyl electrophiles generated an intermediate that cyclized *via* an intramolecular hemiacetal. This tin(IV)-promoted intramolecular hemiketalization served to facilitate the construction of the medium sized rings, which were often generated in high diastereomeric excess (protocol A).[4]

Scheme 1



Scheme 2



A more general and useful annulation approach (Scheme 2) involved the reaction of a β-dicarbonyl-1,3-dianionic equivalent with 1,4- or 1,5-dielectrophiles under Lewis acid catalysis (protocol B).[5] The resultant products were often obtained as single regioisomers, and a high degree of stereochemical control was realized. These results were explained on the basis of an unprecedented neighboring group participation mechanism involving a cyclic oxocarbenium ion intermediate that effectively served as a template for stereoselective carbon–carbon bond formation. This approach has been used in the construction of both bicyclic[5a,b,d] and tricyclic ethers.[5c]

We recognized that these methods could be applied to the synthesis of natural products such as dactylol (**1**). The

[⊗] Abstract published in *Advance ACS Abstracts,* June 15, 1995.

(1) Schmitz, F. J.; Hollenbeak, K. H.; Vanderah, D. J. *Tetrahedron* **1978**, *34*, 2719.

(2) (a) Paquette, L. A.; Ham, W. H. *J. Am. Chem. Soc.* **1987**, *109*, 3025. (b) Gadwood, R. C.; Lett, R. M.; Wissinger, J. E. *J. Am. Chem. Soc.* **1986**, *108*, 6343. (c) Hayasaka, K.; Ohtsuka, T.; Shirahama, H.; Matsumoto, T. *Tetrahedron Lett.* **1985**, *26*, 873. (d) Feldman, K. S.; Wu, M.; Rotella, D. P. *J. Am. Chem. Soc.* **1990**, *112*, 8490.

(3) For a review on the synthesis of eight-membered carbocycles, see: Petasis, N. A.; Patane, M. A. *Tetrahedron* **1992**, *48*, 5757.

(4) (a) Molander, G. A.; Andrews, S. W. *Tetrahedron Lett.* **1989**, *30*, 2351. (b) Molander, G. A.; Shubert, D. C. *J. Am. Chem. Soc.* **1987**, *109*, 6877.

(5) (a) Molander, G. A.; Cameron, K. O. *J. Org. Chem.* **1991**, *56*, 2617. (b) Molander, G. A.; Cameron, K. O. *J. Am. Chem. Soc.* **1993**, *115*, 830. (c) Molander, G. A.; Cameron, K. O. *J. Org. Chem.* **1993**, *58*, 5931. (d) Molander, G. A.; Siedem, C. S. *J. Org. Chem.* **1995**, *60*, 130.

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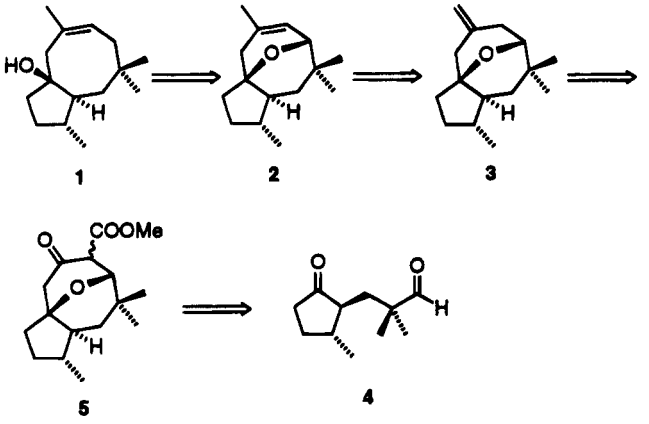
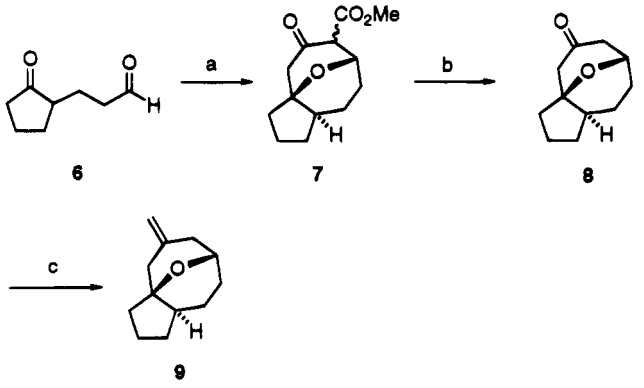
Scheme 3



Scheme 4



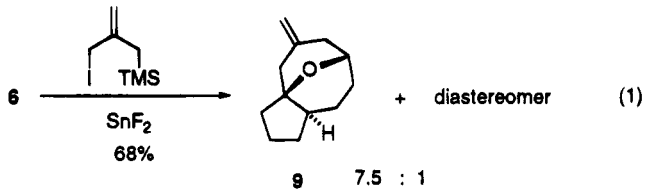
(a) ref. 5c; (b) NaCl, DMSO, H_2O, 140 °C, 56%; (c) $Cp_2TiClCH_2AlMe_2$, THF, 0 °C, 86%.

retrosynthetic analysis of this target is shown in Scheme 3. We envisioned that dactylol could be obtained from the allylic ether **2** by either a Lewis acid mediated ring-opening or a dissolving metal reduction. Intermediate **2** could be obtained from the exocyclic olefin **3** by a catalytic isomerization. In principle, olefin **3** is an excellent candidate for synthesis by either of our annulation protocols; only one step removed from keto aldehyde **4** utilizing protocol A or two steps from **4** *via* the keto ester **5** using protocol B.

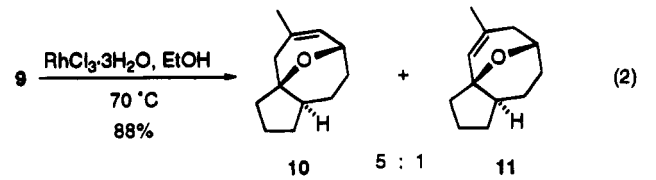
A model study was first undertaken to assess the viability of the proposed synthetic route. Annulation of the 1,5-dicarbonyl compound **6** with 1,3-bis(trimethylsiloxy)-1-methoxybuta-1,3-diene using 15 mol % of $TrSbCl_6$ afforded the annulated product **7** as previously described (Scheme 4).[5c] An X-ray structure of the enol acetate derivative of **7** established the stereochemistry at the ring junction.[5c] Hydrolysis and decarboxylation of the ester group was effected under the conditions described by Krapcho[6] to provide ketone **8**, which was methylenated with the Tebbe reagent[7] to afford the desired exocyclic olefin **9** in modest overall yield.

Olefin **9** could be obtained from **6** more conveniently in one step utilizing annulation protocol A, which proceeded in 68% yield giving a 7.5:1 mixture of diastereoisomers in favor of the desired product **9** (eq 1).

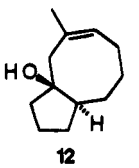
Molecular modeling studies[8] suggested that **10** should be favored over **11** in view of the calculated relative



energy differences between the two. Isomerization of **9** using $RhCl_3 \cdot 3H_2O$[9] afforded an inseparable 5:1 mixture of the isomers **10** and **11** in 88% yield (eq 2). On a small scale selectivity typically was higher (>6:1). The position of the double bond in both isomers was established by homonuclear decoupling experiments.



The conversion of **10** to the desired bicyclic ring system **12** was not trivial and required much experimentation. Upon treatment of a mixture of **10** and **11** with a variety of reagents that have been reported to cleave ethers and/or allylic ethers[10] [Ac_2O, $FeCl_3$;[11] $HS(CH_2)_2SH$, $BF_3 \cdot Et_2O$;[12] DIBALH;[13] TMSI;[14] Me_2BBr, Et_3N;[15] $LiClO_4$, Et_3SiH;[16] $Pd(Ph_3)_4$, Ph_3P, $LiBHEt_3$;[17] *n*-PrMgBr, $NiCl_2(PPh_3)_2$[18]] either no reaction was observed or mixtures of ring cleavage products were obtained in low yield. It is presumed that in the cases where ring cleavage occurred, the tertiary alcohol formed subsequently decomposed in the Lewis acidic reaction mixture. Much the same problems have been encountered by Rigby,[12] who failed to open similar systems cleanly by such methods.

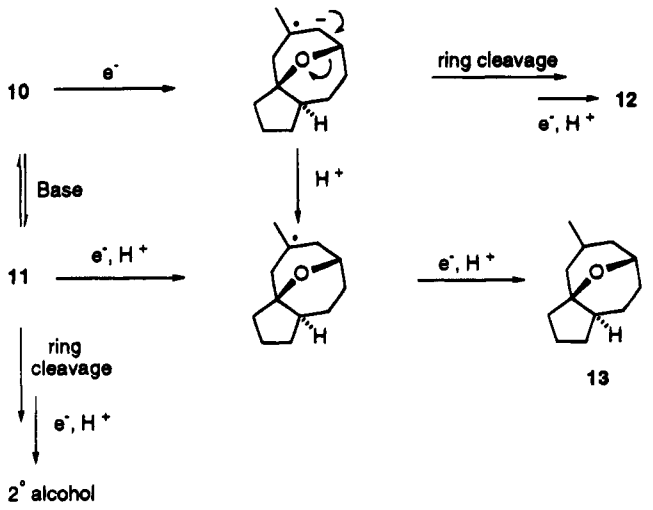


12

There is substantial precedent for the opening of allylically activated cyclic ethers utilizing dissolving metals.[19] Consequently, this approach was attempted in further efforts to convert **10** to **12**. At the low reaction temperatures necessary for some amines (e.g., NH_3, $MeNH_2$), using either Li or Na as the reductant with various cosolvents (e.g., THF, Et_2O, DME), little or none

(6) Krapcho, A. P.; Lovey, A. J. *Tetrahedron Lett.* **1973**, *14*, 957.
(7) Pine, S. H.; Pettit, R. J.; Geib, G. D.; Cruz, S. G.; Gallego, C. H.; Tijerina, T.; Pine, R. D. *J. Org. Chem.* **1985**, *50*, 1212.
(8) Models were generated using Macromodel.
(9) Andrieux, J.; Barton, D. H. R.; Patin, H. *J. Chem. Soc., Perkin Trans. 1* **1977**, 359.
(10) For a review on the cleavage of the ether linkage, see: Bhatt, M. V.; Kulkarni, S. U. *Synthesis* **1983**, 249.
(11) Ganem, B.; Small, V. R., Jr. *J. Org. Chem.* **1974**, *39*, 3728.
(12) Rigby, J. H.; Wilson, J. A. Z. *J. Org. Chem.* **1987**, *52*, 34.
(13) Woo, S.; Keay, B. A. *Tetrahedron Lett.* **1992**, *33*, 2661.
(14) Jung, M. E.; Lyster, M. A. *J. Org. Chem.* **1977**, *42*, 3761.
(15) Guindon, Y.; Therien, M.; Girard, Y.; Yoakim, C. *J. Org. Chem.* **1987**, *52*, 1680.
(16) Wustrow, D. J.; Smith, W. J., III; Wise, L. D. *Tetrahedron Lett.* **1994**, *35*, 61.
(17) Felkin, H.; Swierczewski, G. *Tetrahedron* **1975**, *31*, 2735.
(18) Scott, N. D.; Walker, J. F.; Hansley, V. L. *J. Am. Chem. Soc.* **1936**, *58*, 2442.
(19) (a) Sakai, K.; Ohtsuka, T.; Misumi, S.; Shirahama, H.; Matsumoto, T. *Chem. Lett.* **1981**, 355. (b) Rigby, J. H.; Wilson, J. A. Z. *J. Am. Chem. Soc.* **1984**, *106*, 8217. (c) Kobayashi, T.; Tsuruta, H. *Synthesis* **1980**, 492. (d) Zhou, J.; Lu, G.; Huang, X.; Wu, S. *Synth. Commun.* **1991**, *21*, 435. (e) Harmata, M.; Elahmad, S.; Barnes, C. L. *J. Org. Chem.* **1994**, *59*, 1241.

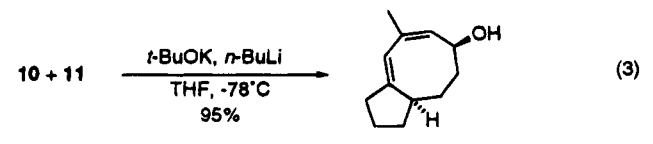
Scheme 5



of **12** was obtained. The best result in the reductive cleavage was obtained in an exothermic reaction when an excess of freshly cut lithium was added to a solution of the olefins **10** and **11** in ethylenediamine/DME (3:1). Under these conditions up to 45% of **12** could be isolated. Two major problems accounted for the low yield of **12**: (a) isomerization of the double bond which resulted in cleavage of the ring from the opposite side to provide the undesired secondary alcohol and (b) formation of the saturated ether **13** which arose from simple reduction of the double bond (Scheme 5). Molecular modeling studies indicate that an unfavorable distortion of the ring system is required to obtain a suitable alignment of the olefinic π-system and the C–O bond necessary for ring cleavage, and this may explain the reluctance of the allylic ether to open efficiently. The identity of **13** was established *via* catalytic hydrogenation of a mixture of **10** and **11** which provided a 1.3:1 mixture of two isomers, the minor of which coeluted with **13** on fused silica capillary gas chromatography and possessed the same NMR spectrum as **13**.

The use of lithium 4,4'-di-*tert*-butylbiphenylide[20] or K/toluene/dicyclohexyl-18-crown-6,[21] which have previously been employed to carry out similar reductions in aprotic media, resulted in very slow reactions with concomitant formation of many byproducts.

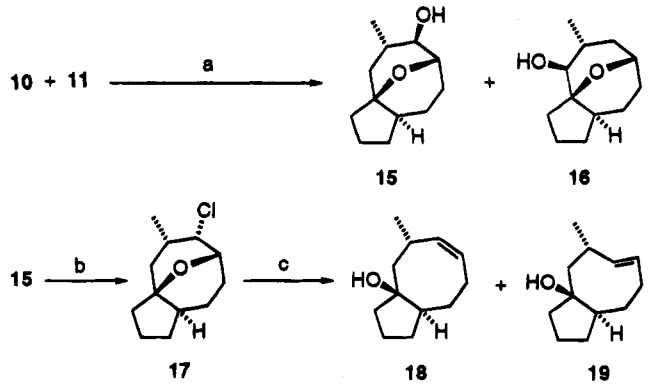
Initially dissatisfied with the modest yields that could be achieved in this reductive cleavage, we attempted several other approaches to effect the desired ring-opening of the tricyclic ether. Thus, allylic deprotonation of the mixture of olefins with Schlosser's base[22] very cleanly gave rise to the secondary alcohol **14** in 95% yield, but no ring-opened products resulting from ether cleavage at the desired site could be detected (eq 3). The use of *tert*-butyllithium also gave rise to the same product.



(3)

(20) Mudryk, B.; Cohen, T. *J. Am. Chem. Soc.* **1991**, *113*, 1866.
(21) Ohsawa, T.; Hatano, K.; Kayoh, K.; Kotabe, J.; Oishi, T. *Tetrahedron Lett.* **1992**, *33*, 5555.
(22) Fujita, K.; Schlosser, M. *Helv. Chim. Acta* **1982**, *65*, 1258.

Scheme 6



(a) BH_3·Me_2S, THF, rt, then NaOH, H_2O_2 ,75%; (b) Ph_3P, NCS, THF, 73%; (c) Na, THF, reflux, 73%.

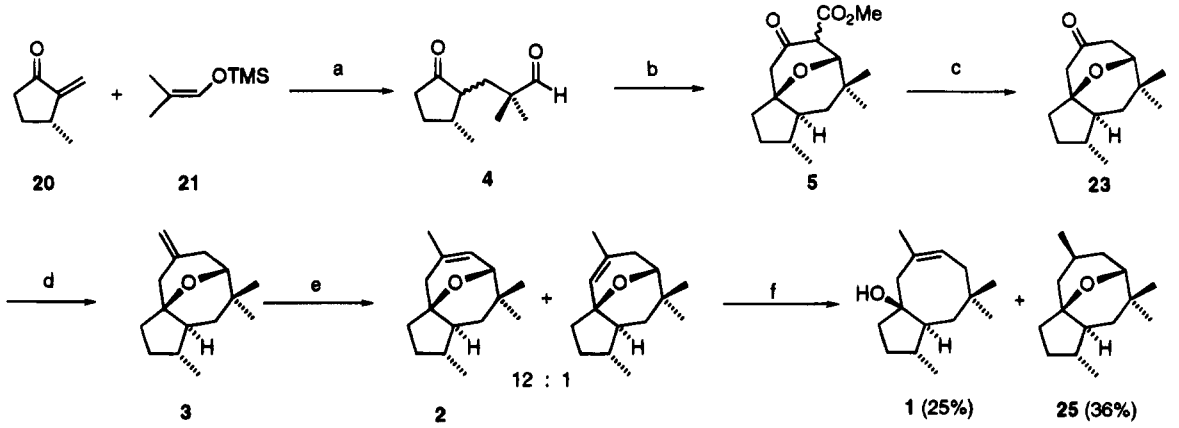
To avoid the problem of olefin isomerization, it was hoped that functionalization of the double bond could be achieved while retaining a handle for opening of the ether bridge (Scheme 6).[23] Thus, hydroboration of the mixture of **10** and **11** afforded a separable mixture of alcohols **15** and **16** in 75% yield. Treatment of **15** with NCS/Ph_3P[24] afforded the chloride **17**. Attempted cleavage of the α-chloro ether **17** with SmI_2[23e] failed. However, treatment of **17** with finely dispersed sodium in THF[23c] led to clean ring-opening and provided an inseparable 1.8:1 mixture of the *cis* and *trans* olefins **18** and **19**, in 53% overall yield from **15**.[25] This mixture was directly treated under the isomerization conditions used previously ($RhCl_3$·$3H_2O$, EtOH), but none of the desired product **12** was detected by GC analysis. As a consequence, no further studies were conducted along this synthetic route.

Now resigned to the reductive ring-opening approach that was only modestly successful in the model system, attention was turned to the synthesis of (+)-dactylol (Scheme 7).

The desired dicarbonyl compound **4** was synthesized from the known (*R*)-3-methyl-2-methylenecyclopentanone **20**,[26] which in turn is readily available in gram quantities from commercial (+)-pulegone in seven steps. Thus, treatment of **20** with the trimethylsilyl enol ether **21**[27] in the presence of the mixed Lewis acid system [$TiCl_4$, $Ti(Oi\text{-}Pr)_4$][28] furnished **4** as an inseparable 5.4:1 mixture of *trans/cis* isomers in 83% yield. The stereochemical assignment of the major product was based upon the fact that the C(3)-methyl groups in the *cis* isomers of 2,3-dialkylcyclopentanones tend to appear upfield ($\Delta\delta$ = 0.22–0.26 ppm) relative to those of the corresponding methyl groups in the *trans* isomers.[29] In the case of **4**, a similar observation was made with the methyl signals appearing at δ 0.78 (minor) and 1.07 ppm (major).

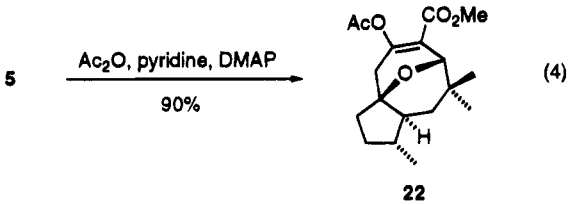
(23) Ring cleavage of β-chloro tetrahydropyrans has been documented: (a) House, H. O.; Ro, R. S. *J. Am. Chem. Soc.* **1958**, *80*, 182. (b) Sammes, P. G.; Street, L. J. *J. Chem. Soc., Chem. Commun.* **1983**, 666. (c) Paul, R.; Riobé, O.; Maumy, M. *Org. Synth.* **1976**, *55*, 62. (d) Fernández, S.; Hernández, E. *Synth. Commun.* **1982**, *12*, 915. (e) Crombie, L.; Rainbow, L. J. *Tetrahedron Lett.* **1988**, *29*, 6517.
(24) Bose, A. K.; Lal, B. *Tetrahedron Lett.* **1973**, *14*, 3937.
(25) Lower selectivity was obtained when the equivalent bromide was used. The latter afforded a 1.5:1 mixture of olefins in favor of the *trans* isomer under the same conditions.
(26) Marx, J. N.; Norman, L. R. *J. Org. Chem.* **1975**, *40*, 1602.
(27) Reissig, H-U; Reichelt, I.; Kunz, T. *Org. Synth.* **1992**, *71*, 189.
(28) Huffman, J. W.; Potnis, S. M.; Satish, A. V. *J. Org. Chem.* **1985**, *50*, 4266.
(29) (a) Pfeffer, P. E.; Osman, S. F. *J. Org. Chem.* **1972**, *37*, 2425. (b) Smith, A. B., III; Wexler, B. A.; Slade, J. S. *Tetrahedron Lett.* **1980**, *21*, 3237.

Scheme 7



(a) $TiCl_4$, $Ti(O\text{-}iPr)_4$, CH_2Cl_2, -95 °C, 83%; (b) CH_2=C(OTMS)CH=C(OTMS)OMe, $TrSbCl_6$, CH_2Cl_2, -78 °C, 77%; (c) NaCl, DMSO, H_2O, 140 °C, 84%; (d) $Cp_2TiClCH_2AlMe_2$, THF, 0 °C, 92%; (e) $RhCl_3 \cdot 3H_2O$, EtOH, H_2O, 70 °C, 96%; (f) Li, $H_2N(CH_2)_2NH_2$, DME, 40 °C.

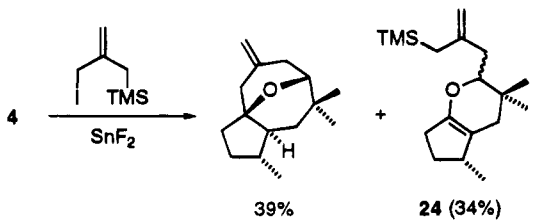
Attempts to equilibrate this mixture (K_2CO_3/MeOH) to afford the pure *trans* isomer were unsuccessful and led to significant decomposition of the starting material and even increased amounts of the *cis* isomer. Treatment of **4** under the conditions of annulation protocol B led to a mixture of keto–enol tautomers of **5** in 77% yield. This mixture was derivatized with Ac_2O/pyridine/DMAP to afford a single enol acetate **22** in 90% yield (eq 4) thereby demonstrating that the annulation had proceeded with complete regio- and stereoselectivity.



(4)

The fact that only one product was obtained dispelled initial fears that incorporation of a quaternary center adjacent to an aldehyde, as in **4**, would lead to a lowering of regioselectivity in the annulation. It was unclear what had become of the *cis* isomer of **4** during the reaction, as no annulated products arising from it could be isolated. Equilibration of such compounds under the reaction conditions has been shown not to occur, even with compounds that epimerize readily.[5c] Decarboxylation of **5** afforded the ketone **23**, which was methylenated with Tebbe's reagent, providing **3** in excellent overall yield.

Attempted formation of **3** by annulation protocol A only led to low yields of the desired product as a mixture of diastereoisomers. The main reason for this low yield was that a substantial amount of the bicyclic ether **24** was formed, probably by elimination of a tin alkoxide from the hemiketal intermediate (eq 5).



(5)

Isomerization of **3** under the conditions used for the model system provided a 96% yield of a 12:1 mixture of olefins in favor of the desired isomer **2**. Dissolving metal reduction of this mixture provided a low yield of (+)-dactylol {$[\alpha]^{24}_D$ +21.0 (c = 1.16, $CHCl_3$), lit.[1] $[\alpha]_D$ +22.5 (c = 1.76, $CHCl_3$)}, identical in all respects to the natural material. The cleavage of the ether bridge of **2** proved to be even more difficult than that of the model compound **10**, and optimization (Li, DME/$H_2N(CH_2)_2NH_2$, 40 °C) led to a 25% isolated yield of **1**. The major product isolated, **25**, was formed by simple reduction of the double bond.

In summary, this synthesis demonstrates the application of a [3 + 5] annulation protocol to the synthesis of dactylol. Although rapid entry is gained to the carbocyclic framework by this approach, difficulties remain in unleashing the eight-membered ring by reductive cleavage of the ether. Alternative methods that will permit facile cleavage of the ether bridge in other systems are currently being investigated.

Experimental Section

Reagents. THF was distilled immediately prior to use from benzophenone ketyl under Ar. Dichloromethane and 1,2-dimethoxyethane were freshly distilled from CaH_2. Standard benchtop techniques were employed for handling air sensitive reagents,[30] and all reactions were carried out under argon.

(1*R, 3*S**, 6*S**)-2-Oxatricyclo[6.3.1.0^{1,6}]dodecan-11-one (8).** A mixture of annulated products **7**[5c] (2.136 g, 9.0 mmol) was dissolved in DMSO (10 mL), and water (850 μL, 53.1 mmol) and NaCl (850 mg, 14.5 mmol) were added. The mixture was warmed to 140 °C over 40 min and kept at this temperature for 90 min. The mixture was then cooled. Water (10 mL) was added, and the product was extracted into Et_2O. The organic layer was dried ($MgSO_4$), concentrated *in vacuo*, and purified by flash chromatography (10:1 hexanes/ethyl acetate) to provide 900 mg (56%) of **8**, >99% pure by GC analysis: IR (neat) 1714 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.45 (t, J = 6.8 Hz, 1H), 2.70 (d, J = 7.7 Hz, 1H), 2.66 (d, J = 7.3 Hz, 1H), 2.27 (dd, J = 6.1, 1.8 Hz, 1H), 2.22–2.25 (m, 1H), 2.00–2.11 (m, 1H), 1.77–1.90 (m, 3H), 1.48–1.75 (m, 6H), 1.28–1.36 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 209.1, 81.4, 69.8, 50.3, 45.2, 42.2, 40.2, 28.3, 24.6, 20.8, 18.0; HRMS calcd for $C_{11}H_{16}O_2$ 180.1150, found 180.1147; LRMS (EI) m/z 180 (100). Anal. Calcd for $C_{11}H_{16}O_2$: C, 73.33; H, 8.89. Found: C, 73.25; H, 8.97.

(1*R,3*S**,6*S**)-11-Methylene-2-oxatricyclo[6.3.1.0^{1,6}]-dodecane (9). Method A.** To a stirred solution of ketone **8** (613 mg, 3.41 mmol) in THF (15 mL) at 0 °C was added Tebbe's reagent (0.5 M in toluene, 7.4 mL, 3.70 mmol). After stirring

(30) Brown, H. C. *Organic Syntheses via Boranes*; Wiley: New York, 1975.

for 1 h at 0 °C, the mixture was diluted with Et_2O (80 mL) and dry methanol (40 drops) was cautiously added. Celite was added, and the mixture was filtered through a pad of Celite. The filter cake was washed with Et_2O, and the combined filtrate and washings were concentrated to give a red oil. Flash chromatography (30:1 hexanes/ethyl acetate) afforded 521 mg (86%) of **9**, >98% pure by GC analysis: IR (neat) 3072, 2951 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.70–4.74 (m, 2H), 4.10–4.15 (m, 1H), 2.50–2.58 (m, 1H), 2.42–2.49 (m, 1H), 2.05–2.13 (m, 2H), 1.89–2.02 (m, 2H), 1.62–1.77 (m, 5H), 1.45–1.58 (m, 2H), 1.24–1.32 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.2, 109.3, 80.0, 69.0, 44.1, 41.9, 41.1, 39.0, 30.9, 25.2, 21.6, 21.0; HRMS calcd for $C_{12}H_{18}O$ 178.1358, found 178.1352; LRMS (EI) m/z 178 (75), 41 (100). Anal. Calcd for $C_{12}H_{18}O$: C, 80.90; H, 10.11. Found: C, 81.15; H, 9.90.

(1*R,3*S**,6*S**)-11-Methylene-2-oxatricyclo[6.3.1.0^{1,6}]-dodecane (9). Method B.** To a stirred solution of 2-(3-oxopropyl)cyclopentanone[5c] (1.825 g, 13.0 mmol) and 3-iodo-2-(trimethylsilylmethyl)propene[4] (3.75 g, 14.8 mmol) in dry THF (115 mL) was added SnF_2 (3.54 g, 22.6 mmol), and the mixture was stirred overnight. The resultant yellow suspension was poured into saturated aqueous $NaHCO_3$ and extracted with Et_2O. The combined organic extract was washed with 1 M NaOH and then brine and then dried ($MgSO_4$). Concentration followed by flash chromatography (50:1 hexanes/ethyl acetate) afforded 1.39 g (60%) of **9** and 192 mg (8%) of a diastereoisomer.

(1*R,3*S**,6*S**)-2-Oxa-11-methyltricyclo[6.3.1.0^{1,6}]dodec-11-ene (10) and (1*R**,3*S**,6*S**)-2-Oxa-11-methyltricyclo-[6.3.1.0^{1,6}]dodec-10-ene (11).** To a solution of olefin **9** (447 mg, 2.5 mmol) in degassed ethanol (15 mL) was added $RhCl_3 \cdot 3H_2O$ (20 mg) and water (150 μL). The mixture was heated at reflux for 3 h, diluted with Et_2O, and filtered through a pad of Celite. The solution was dried ($MgSO_4$) and concentrated to provide 394 mg (88%) of a 6:1 mixture of **10** and **11**, >98% pure by GC analysis: ^1H NMR (400 MHz, $CDCl_3$) **major** δ 5.30–5.35 (m, 1H), 4.30–4.55 (m, 1H), 2.38 (d, J = 18.2 Hz, 1H), 1.52–1.95 (m, 13H), 1.37–1.44 (m, 1H), 1.10–1.18 (m, 1H); **minor** (partial spectrum) δ 5.38–5.41 (m, 1H), 4.22–4.28 (m, 1H), 2.46 (dd, J = 18.5, 5.1 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) **major** δ 133.6, 121.9, 78.4, 69.6, 43.8, 40.9, 38.9, 29.3, 22.7, 22.3, 21.3, 18.6; **minor** δ 133.0, 127.2, 78.6, 67.6, 42.6, 39.0, 33.8, 27.6, 26.4, 23.0, 22.2, 18.4; HRMS calcd for $C_{12}H_{18}O$ 178.1358, found 178.1357; LRMS (EI) m/z 178 (100). Anal. Calcd for $C_{12}H_{18}O$: C, 80.90; H, 10.11. Found: C, 80.71; H, 10.10.

(1*R,8*R**)-1-Hydroxy-3-methylbicyclo[6.3.0]dodec-3-ene (12).** To a solution of **10** and **11** (51.5 mg, 0.29 mmol) in a mixture of dry degassed ethylenediamine (1.5 mL) and 1,2-dimethoxyethane (0.5 mL) containing a glass coated stirring bar was added freshly sliced lithium pieces (10-fold excess). An immediate deep blue color was seen, and an exothermic reaction was noted. Stirring was continued for 15 min, and then the mixture was quenched with MeOH and water. The products were extracted into ethyl acetate, and the organic layer was washed with water and then brine and then dried ($MgSO_4$). Flash chromatography (30:1 hexanes/ethyl acetate) afforded, in order of elution: 14.0 mg (27%) of **13**, 96% pure by GC analysis: ^1H NMR (400 MHz, $CDCl_3$) δ 4.03–4.11 (m, 1H), 2.02–2.15 (m, 1H), 1.90–2.00 (m, 1H), 1.81–1.21 (m, 14H), 0.86 (d, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 79.3, 68.0, 44.2, 42.2, 41.6, 39.0, 32.8, 25.3, 23.8, 23.2, 23.1, 22.3; HRMS calcd for $C_{12}H_{20}O$ 180.1514, found 180.1506; LRMS (EI) m/z 180 (45), 41 (100): followed by 23.4 mg (45%) of **12**, 99% pure by GC analysis: IR (neat) 3490 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 5.39 (t, J = 8.4 Hz, 1H), 2.38 (d, J = 13.5 Hz, 1H), 2.23 (d, J = 13.5 Hz, 1H), 2.06–2.18 (m, 1H), 1.90–2.00 (m, 1H), 1.81 (s, 3H), 1.81 (s, 1H), 1.36–1.75 (m, 10H), 1.23–1.31 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 135.1, 125.6, 82.0, 47.7, 41.7, 41.0, 33.0, 27.3, 26.9, 25.8, 23.5, 19.7; HRMS calcd for $C_{12}H_{20}O$ 180.1514, found 180.1512; LRMS (EI) m/z 180 (50), 84 (100). Anal. Calcd for $C_{12}H_{20}O$: C, 80.00; H, 11.11. Found: C, 79.84; H, 11.17.

(1*R,3*R**,6*R**,11*S**)-11-Methyl-2-oxatricyclo[6.3.1.0^{1,6}]-dodecane (13).** A solution of olefins **10** and **11** (51 mg, 0.29 mmol) in ethyl acetate (1 mL) was hydrogenated using 10% Pd/C (10 mg) under 1 atm of hydrogen using a balloon. The mixture was filtered through Celite and concentrated to afford 46 mg (89%) of a 1.3:1 mixture of products, >99% pure by GC analysis. The spectral data for the minor product were identical with **13**.

(5*R,8*S**)-5-Hydroxy-3-methylbicyclo[6.3.0]dodeca-1,3-diene (14).** To a mixture of olefins **10** and **11** (49.5 mg, 0.28 mmol) and *t*-BuOK (38 mg, 0.34 mmol) in THF (1 mL) at −78 °C was added *n*-BuLi (1.3 M in hexanes, 259 μL, 0.34 mmol). The resultant mixture was warmed to −50 °C, stirred for 2 h, and then warmed to ambient temperature. Water was added, and the mixture was extracted with ethyl acetate, washed with brine, and dried ($MgSO_4$). Concentration followed by flash chromatography (5:1 hexanes/ethyl acetate) afforded 47.0 mg (95%) of the diene **14** as a white solid: mp 61–62 °C; IR (Nujol mull) 3850, 3626, 3280 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 5.47 (s, 1H), 5.14 (d, J = 6.6 Hz, 1H), 4.65–4.73 (m, 1H), 2.34–2.51 (m, 2H), 2.18–2.29 (m, 1H), 1.75–1.88 (m, 3H), 1.74 (s, 3H), 1.47–1.70 (m, 5H), 1.21–1.34 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.0, 132.6, 127.8, 120.6, 69.5, 44.7, 35.4, 35.1, 34.4, 25.8, 24.6, 21.8; LRMS (EI) m/z 178 (45), 91 (100).

(1*R,3*R**,6*R**,11*S**,12*S**)-12-Hydroxy-11-methyl-2-oxatricyclo[6.3.1.0^{1,6}]dodecane (15) and (1*R**,3*R**,6*S**,-10*R**,11*S**)-10-Hydroxy-11-methyl-2-oxatricyclo[6.3.1.0^{1,6}]-dodecane (16).** To a solution of olefins **10** and **11** (500 mg, 2.8 mmol) in THF (18 mL) was added $BH_3 \cdot Me_2S$ (10 M, 270 μL, 2.7 mmol), and the mixture was stirred at room temp for 90 min. To the solution was added sequentially water (1.5 mL), 30% H_2O_2 (4.5 mL), and 3 M NaOH (13 mL), and the mixture was stirred an additional 90 min. The product was extracted into Et_2O, and the organic extracts were combined, washed with brine, and dried ($MgSO_4$). Concentration followed by flash chromatography (4:1 hexanes/ethyl acetate) provided 355 mg (64%) of **15**, 99% pure by GC analysis: mp 75–77 °C; IR (neat) 3407 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.72–3.78 (m, 1H), 3.18–3.26 (m, 1H), 1.67–1.96 (m, 6H), 1.42–1.65 (m, 6H), 1.29–1.36 (m, 1H), 1.07–1.16 (m, 1H), 1.03 (d, J = 6.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 79.1, 77.3, 77.1, 43.8, 42.0, 37.9, 32.6, 27.1, 23.0, 21.4, 17.6, 17.5; HRMS calcd for $C_{12}H_{20}O_2$ 196.1463, found 196.1470; LRMS (EI) m/z 196 (20), 121 (100). Anal. Calcd for $C_{12}H_{20}O_2$: C, 73.47; H, 10.20. Found: C, 73.51; H, 10.60: followed by 62 mg (11%) of **16**, >99% pure by GC analysis: mp 95–97 °C; IR (Nujol mull) 3849, 3365 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.01–4.40 (m, 1H), 3.20 (t, J = 8.3 Hz, 1H), 1.82–2.05 (m, 4H), 1.53–1.80 (m, 7H), 1.44–1.52 (m, 1H), 1.35 (d, J = 7.5 Hz, 1H), 1.05–1.15 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 84.1, 79.4, 66.6, 42.6, 34.6, 32.6, 32.4, 27.8, 24.6, 21.3, 18.5, 17.0; HRMS Calcd for $C_{12}H_{20}O_2$ 196.1463, found 196.1472; LRMS (EI) m/z 196 (50), 139 (100). Anal. Calcd for $C_{12}H_{20}O_2$: C, 73.47; H, 10.20. Found: C, 73.05; H, 10.48.

(1*R,3*R**,6*R**,11*S**,12*S**)-12-Chloro-11-methyl-2-oxatricyclo[6.3.1.0^{1,6}]dodecane (17).** A solution of *N*-chlorosuccinimide (108 mg, 0.81 mmol) in THF (2 mL) was added to a solution of Ph_3P (211 mg, 0.81 mmol) in THF (2 mL). A white precipitate formed. A solution of **15** (121 mg, 0.62 mmol) in THF (2 mL) was added dropwise to the suspension, and the reaction mixture was stirred at room temp for 2 h and then heated to reflux for a further 30 min. The mixture was partitioned between ethyl acetate and water, and the organic layer was washed with brine and dried ($MgSO_4$). Concentration followed by flash chromatography (40:1 hexanes/ethyl acetate) afforded 110 mg of **17** which was shown by GC to be contaminated with the olefin **10** (<10%). The crude material was used directly in the next step: IR (neat) 2943 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.48 (t, J = 7.0 Hz, 1H), 4.20–4.28 (m, 1H), 2.27–2.38 (m, 1H), 1.33–1.99 (m, 13H), 1.19 (d, J = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 78.9, 70.3, 64.2, 42.8, 42.3, 37.5, 31.0, 30.6, 22.0, 21.7, 20.9, 18.0; LRMS (EI) m/z 214 (25), 94 (100).

***cis*- and *trans*-(1*R**,3*S**,8*S**)-1-Hydroxy-3-methylbicyclo-[6.3.0]dodec-4-ene (18 and 19).** Several small pieces of freshly cleaned sodium were heated with toluene until a fine dispersion of sodium was obtained. The toluene was removed *via* a cannula under argon pressure, a solution of crude chloride **17** (83.6 mg, *ca.* 0.34 mmol) in THF (4 mL) was added,

and the mixture was heated to reflux. After 1 h the mixture was cooled and then quenched with *i*-PrOH. The products were extracted into ethyl acetate, and the organic layer was washed with brine and dried ($MgSO_4$). Concentration followed by flash chromatography (30:1 hexanes/ethyl acetate) afforded 44.0 mg (53% from **15**) of a *ca.* 1.8:1 mixture of **18** and **19**, 98% pure by GC analysis: IR (neat) 3476, 3004, 2950 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ ***cis*** 5.43–5.60 (m, 1H), 5.39–5.42 (dd, J = 10.4, 7.6 Hz, 1H), 2.75–2.82 (m, 1H), 2.50–2.60 (m, 1H), 1.26–2.03 (m, 13H), 1.02 (d, J = 6.8 Hz, 3H); ***trans*** δ 5.43–5.60 (m, 1H), 5.32 (dd, J = 15.8, 10.4 Hz, 1H), 2.60–2.70 (m, 1H), 2.20–2.27 (m, 1H), 2.15 (dd, J = 14.0, 4.6 Hz, 1H), 1.26–2.03 (m, 12H), 1.00 (d, J = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 138.2, 138.2, 130.7, 127.8, 82.5, 80.8, 56.9, 51.3, 49.6, 47.8, 47.3, 42.7, 37.1, 36.7, 34.6, 34.3, 33.7, 30.9, 26.9, 25.4, 23.9, 23.3, 23.1, 19.6; LRMS (EI) m/z 180 (15), 162 (60), 134 (100).

(3*R*)-3-Methyl-2-(2,2-dimethyl-3-oxopropyl)cyclopentanone (4). $TiCl_4$ (Aldrich, 1 M in CH_2Cl_2, 13.6 mL, 13.6 mmol) was diluted with CH_2Cl_2 (45 mL) and cooled to −78 °C. To the stirred solution was added Ti(O*i*-Pr)$_4$ (2.6 g, 9.0 mmol), and the mixture was stirred for 5 min and then cooled to −95 °C. A cold (−78 °C) solution of (3*R*)-3-methyl-2-methylenecyclopentanone (**20**)[26] (0.691 g, 7.2 mmol) in CH_2Cl_2 (15 mL) was added, the mixture was stirred for 5 min, and then a cold (−78 °C) solution of 2-methyl-1-[(trimethylsilyloxy)propene] (**21**)[27] (1.083 g, 9.8 mmol) in CH_2Cl_2 (15 mL) was added. After 30 min the cooling bath was removed and the reaction was warmed to *ca.* 10 °C and then quenched with 5% K_2CO_3 (40 mL). The mixture was extracted with Et_2O, and the combined organic extract was dried ($MgSO_4$). Concentration followed by flash chromatography (10:1 hexanes/ethyl acetate) provided 0.949 g (83%) of **4** as a 5.4:1 mixture of diastereoisomers, >99% pure by GC analysis: IR (neat) 1738, 1723 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) **major** δ 9.46 (s, 1H), 2.22–2.32 (m, 1H), 1.97–2.10 (m, 2H), 1.83 (dd, J = 14.4, 7.1 Hz, 1H), 1.60–1.73 (m, 1H), 1.44–1.52 (m, 1H), 1.30–1.41 (m, 2H), 1.07 (d, J = 6.4 Hz, 3H), 1.02 (s, 3H), 1.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) **major** δ 218.0, 205.7, 52.9, 45.5, 38.5, 37.1, 35.2, 29.2, 22.6, 21.3, 19.1; **minor** δ 218.8, 205.7, 51.0, 45.6, 33.7, 33.3, 31.5, 27.7, 21.7, 21.6, 14.7; HRMS calcd for $C_{11}H_{18}O_2$ 182.1307, found 182.1306; LRMS (EI) m/z 183 (80), 153 (100).

(1*R*,3*S*,6*S*,7*R*)-12-(Methoxycarbonyl)-2-oxa-4,4,7-trimethyltricyclo[6.3.1.0^{1,6}]dodecan-11-one (5). To a stirred solution of the mixture of isomers **4** (0.800 g, 4.4 mmol) in CH_2Cl_2 (45 mL) at −78 °C was added a solution of $TrSbCl_6$ (165 mg, 6.5 mol %) in CH_2Cl_2 (40 mL). After 5 min, a solution of 1,3-bis(trimethylsiloxy)-1-methoxybuta-1,3-diene (1.451 g, 5.6 mmol) in CH_2Cl_2 (55 mL) was added down the side of the flask over 10 min. The mixture was stirred at −78 °C for 4.5 h and then warmed to room temperature. Concentration followed by flash chromatography (20:1 hexanes/ethyl acetate) afforded 948 mg (77%) of annulation products as a mixture of tautomers: IR (neat) 1741, 1720, 1658 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) **enol form** δ 12.20 (br s, 1H), 4.35 (s, 1H), 3.67 (s, 3H), 2.65 (d, J = 18.7 Hz, 1H), 2.18 (m, 1H), 2.13 (d, J = 18.5 Hz, 1H), 1.94–2.04 (m, 1H), 1.70–1.82 (m, 2H), 1.54 (dd, J = 14.4, 8.7 Hz, 1H), 1.29 (d, J = 14.7 Hz, 1H), 1.20 (s, 3H), 0.94 (d, J = 6.9 Hz, 3H), 0.82–0.92 (m, 2H), 0.70 (s, 3H); **keto form** δ 4.26 (s, 1H), 3.69 (s, 3H), 3.46 (s, 1H), 3.01 (d, J = 14.3 Hz, 1H), 2.26 (dd, J = 15.1, 1.0 Hz, 1H), 2.17 (m, 1H), 1.88–2.00 (m, 2H), 1.67–1.77 (m, 1H), 1.39–1.49 (m, 1H), 1.19 (s, 3H), 1.05–1.18 (m, 3H), 0.93 (d, J = 6.7 Hz, 3H), 0.88 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) **enol form** δ 171.1, 170.7, 98.3, 79.1, 74.7, 51.8, 50.8, 39.6, 38.9, 38.4, 32.8, 31.1, 28.6, 28.0, 20.0; **keto form** δ 203.9, 169.4, 83.5, 81.6, 56.0, 52.5, 51.0, 50.1, 39.1, 37.8, 31.8, 31.2, 31.1, 29.3, 28.7, 19.3; LRMS (EI) m/z 280 (70), 181 (100). Anal. Calcd for $C_{16}H_{24}O_4$: C, 68.57; H, 8.57. Found: C, 68.49; H, 8.60.

(1*R*,3*S*,6*S*,7*R*)-11-Acetoxy-12-(methoxycarbonyl)-2-oxa-4,4,7-trimethyltricyclo[6.3.1.0^{1,6}]dodec-11-ene (22). To the mixture of annulation products **5** (95 mg, 0.34 mmol) was added pyridine (5 mL), Ac_2O (1 mL), and DMAP (cat.) and the solution was stirred overnight. The mixture was concentrated and partitioned between Et_2O and water. The organic layer was washed with water and then brine and dried ($MgSO_4$). Concentration followed by flash chromatography (10:1 hexanes/ethyl acetate) afforded 98.5 mg (90%) of **22** as a viscous oil which solidified upon scratching, >99% pure by GC analysis: mp 64–65 °C; $[\alpha]^{29}_D$ +19.7 (c = 1.165, $CHCl_3$); IR (neat) 1762, 1722, 1673 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.50 (s, 1H), 3.66 (s, 3H), 2.53 (dd, J = 18.4, 0.9 Hz, 1H), 2.09–2.16 (m, 5H), 1.90–2.02 (m, 1H), 1.67–1.86 (m, 3H), 1.32 (d, J = 15.2 Hz, 1H), 1.16–1.25 (m, 4H), 1.00–1.15 (m, 1H), 0.92 (d, J = 7.7 Hz, 3H), 0.67 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 164.7, 153.7, 118.9, 79.8, 76.8, 51.7, 51.5, 39.5, 39.4, 38.7, 32.9, 31.5, 31.5, 28.1, 28.1, 20.8, 20.0; HRMS calcd for $C_{18}H_{26}O_5$ 322.1780, found 322.1765; LRMS (EI) m/z 322 (7), 280 (100). Anal. Calcd for $C_{18}H_{26}O_5$: C, 67.08; H, 8.07. Found: C, 67.11; H, 7.92.

(1*R*,3*S*,6*S*,7*R*)-2-Oxa-4,4,7-trimethyltricyclo[6.3.1.0^{1,6}]dodecan-11-one (23). Following the procedure used for the decarboxylation of **7**, a mixture of annulated products **5** (596 mg, 2.13 mmol) was treated in the same manner, to afford after flash chromatography (10:1 hexanes/ethyl acetate) 399 mg (84%) of **23**, >96% pure by GC analysis: $[\alpha]^{29}_D$ −16.6 (c = 1.06, $CHCl_3$); IR (neat) 1718 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.87 (t, J = 4.3 Hz, 1H), 2.67 (d, J = 14.4 Hz, 1H), 2.52–2.56 (m, 2H), 2.13–2.25 (m, 2H), 1.84–2.02 (m, 2H), 1.67–1.77 (m, 1H), 1.38–1.48 (m, 2H), 1.15 (s, 3H), 1.02–1.14 (m, 2H), 0.92 (d, J = 6.6 Hz, 3H), 0.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 208.9, 83.0, 79.2, 52.5, 50.5, 41.9, 39.5, 38.2, 32.4, 31.5, 31.2, 29.3, 29.0, 19.5; HRMS calcd for $C_{14}H_{22}O_2$ 222.1620, found 222.1613; LRMS (EI) m/z 222 (100). Anal. Calcd for $C_{14}H_{22}O_2$: C, 75.67; H, 9.91. Found: C, 75.67; H, 9.98.

(1*R*,3*S*,6*S*,7*R*)-11-Methylene-2-oxa-4,4,7-trimethyltricyclo[6.3.1.0^{1,6}]dodecane (3). Following the procedure used for the methylenation of **8**, treatment of **23** (156.5 mg, 0.70 mmol) with Tebbe's reagant, followed by flash chromatography (30:1 hexanes/ethyl acetate), afforded 142.4 mg (92%) of **3**, >97% pure by GC analysis: $[\alpha]^{26}_D$ −27.7 (c = 0.725, $CHCl_3$); IR (neat) 3070, 2951 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 4.65–4.70 (m, 2H), 3.52 (d, J = 6.4 Hz, 1H), 2.35–2.50 (m, 3H), 2.05–2.15 (m, 2H), 1.85–1.97 (m, 2H), 1.62–1.77 (m, 2H), 1.30 (d, J = 14.4 Hz, 1H), 1.10 (s, 3H), 0.97–1.08 (m, 2H), 0.91 (d, J = 6.6 Hz, 3H), 0.83 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.7, 108.4, 81.1, 78.5, 50.5, 45.6, 39.6, 39.0, 34.7, 33.3, 32.5, 31.7, 30.7, 28.8, 19.4; HRMS calcd for $C_{15}H_{24}O$ 220.1827, found 220.1828; LRMS (EI) m/z 220 (99), 205 (100). Anal. Calcd for $C_{15}H_{24}O$: C, 81.82; H, 10.91. Found: C, 81.74; H, 10.87.

(1*R*,3*S*,6*S*,7*R*)-2-Oxa-4,4,7,11-tetramethyltricyclo[6.3.1.0^{1,6}]dodec-11-ene (2). Following the procedure used for the isomerization of **9**, treatment of **3** (596 mg, 2.13 mmol) in the same manner provided 219.6 mg (96%) of a 12:1 isomeric mixture of alkenes in favor of **2**, >98% pure by GC analysis: ^1H NMR (400 MHz, $CDCl_3$) **major** δ 5.44–5.49 (m, 1H), 3.69–3.74 (m, 1H), 2.34 (d, J = 17.6 Hz, 1H), 2.05–2.14 (m, 1H), 1.91–2.01 (m, 1H), 1.67–1.81 (m, 3H), 1.66 (s, 3H), 1.57 (dd, J = 14.0, 7.2 Hz, 1H), 1.26 (d, J = 14.0 Hz, 1H), 1.13 (s, 3H), 1.02–1.11 (m, 2H), 0.91 (d, J = 6.7 Hz, 3H), 0.75 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) **major** δ 133.2, 120.9, 79.1, 77.7, 51.9, 41.4, 40.2, 39.5, 32.7, 32.2, 31.7, 28.6, 27.8, 22.9, 20.3; **minor** δ 131.5, 127.5, 78.8, 76.6, 51.5, 37.7, 36.4, 32.8, 32.3, 31.2, 30.5, 29.1, 28.7, 22.7, 19.6; HRMS calcd for $C_{15}H_{24}O$ 220.1827, found 220.1815; LRMS (EI) m/z 220 (100). Anal. Calcd for $C_{15}H_{24}O$: C, 81.82; H, 10.91. Found: C, 81.66; H, 11.01.

(+)-Dactylol (1). Using the procedure employed for the synthesis of **12** except carrying out the reaction at 40 °C, a mixture comprised of **2** and its olefinic isomer (18.6 mg, 0.085 mmol) provided, after flash chromatography (30:1 hexanes/ethyl acetate), 6.6 mg (35%) of **25**: IR (neat) 2951 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 3.42 (d, J = 5.8 Hz, 1H), 2.03–2.14 (m, 1H), 1.94–2.03 (m, 1H), 1.84–1.93 (m, 1H), 1.74–1.82 (m, 2H), 1.56–1.70 (m, 2H), 1.42–1.54 (m, 2H), 1.30 (d, J = 12.7 Hz, 1H), 1.19–1.28 (m, 1H), 1.12 (s, 3H), 0.95–1.09 (m, 2H), 0.91 (d, J = 6.5 Hz, 3H), 0.82 (s, 3H), 0.81 (d, J = 5.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 79.6, 78.0, 49.7, 45.5, 40.3, 39.9, 35.7, 34.4, 31.9, 31.9, 31.5, 29.1, 24.8, 23.5, 19.5; HRMS calcd for $C_{15}H_{26}O$ 222.1984, found 222.1996; LRMS (EI) m/z 222 (100): followed by 4.7 mg (25%) of dactylol **1**: mp 50–51 °C (lit. mp 50.3–51.5 °C[1]); $[\alpha]^{24}_D$ +21.0 (c = 1.16, $CHCl_3$); IR (CCl_4 mull) 3490, 2950, 1468 cm^{-1}; ^1H NMR (400 MHz, C_6D_6) δ 5.49

(t, J = 8.4 Hz, 1H), 2.21 (d, J = 13.4 Hz, 1H), 2.07 (d, J = 13.4 Hz, 1H), 1.85–1.95 (m, 2H), 1.82 (s, 3H), 1.71–1.80 (m, 1H), 1.60–1.70 (m, 1H), 1.49–1.57 (m, 2H), 1.46 (dd, J = 15.0, 7.9 Hz, 1H), 1.33 (br s, 1H), 0.95–1.09 (m, 2H), 0.91 (d, J = 6.6 Hz, 3H), 0.90 (s, 3H), 0.85 (s, 3H), 0.71 (d, J = 14.6 Hz, 1H); ^{13}C NMR (100 MHz, C_6D_6) δ 135.9, 124.6, 82.8, 52.9, 43.1, 40.4, 39.4, 39.3, 36.5, 35.2, 29.5, 29.3, 28.9, 27.9, 19.2; HRMS calcd for $C_{15}H_{26}O$ 222.1984, found 222.1987; LRMS (EI) m/z 222 (100).

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Supporting Information Available: ^{1}H and ^{13}C NMR spectra of compounds for which no elemental analysis was obtained and dactylol **1** (14 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of this journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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