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Catalytic Enantioselective Approach to the Stereodivergent Synthesis of (+)-Lasubines I and II

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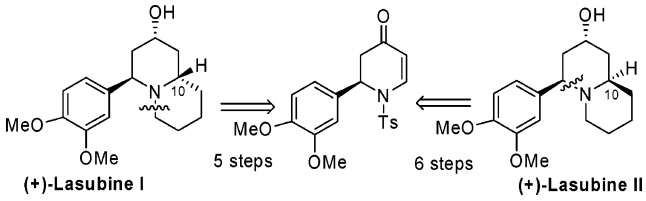

A concise and efficient approach to the stereodivergent synthesis of (+)-lasubines I and II is described. The key common intermediate is a chiral *N*-sulfonyl 2,3-dihydropyridone obtained by a novel Cu-catalyzed asymmetric formal aza-Diels−Alder reaction between *N*-tosyl aldimines and Danishefsky's diene.

Indolizidine, quinolizidine, and piperidine alkaloids encompass a large group of natural products that display a broad range of biological activities.[1] Therefore, intense research efforts have been devoted to the development of new approaches for their preparation.[2] Lasubines I and II are two quinolizidine alkaloids isolated from plants of the *Lythraceae* family, which differ only in the configuration at C-10. Since their isolation by Fuji et al. in 1978[3] many racemic syntheses of lasubines I and II have been reported,[4] and more recently a great effort has been devoted to the enantioselective synthesis of these compounds, mainly the natural (−)-enantiomer. Among the enantioselective syntheses of lasubines I[5] and II[5b,6] reported to date, almost all of them are based on the use of either chiral auxiliary or chiral pool approaches. To the best of our knowledge, the only exception to this trend is the recent work of Rovis et al. on the synthesis of (+)-lasubine II, in which the key step for the enantioselective construction of the quinolizidine skeleton is a catalytic asymmetric Rh-mediated [2+2+2] cycloaddition between an alkenyl isocyanate and a terminal alkyne.[6h]

Herein, we describe a concise enantioselective and stereodivergent synthesis of (+)-lasubines I and II from a common chiral *N*-tosyl 2,3-dihydro-4-pyridone. This key intermediate was obtained by application of a catalytic asymmetric Cu-mediated aza-Diels−Alder reaction of *N*-sulfonyl imines and Danishefsky's diene recently developed in our group.[7]

Retrosynthetically, as shown in Scheme 1, we envisioned that lasubines I and II could be synthesized from the same *N*-tosyl 2,3-dihydro-4-pyridone intermediate **1** by applying stereochemically complementary approaches for the construction of the second ring of the quinolizidine skeleton. Thus, the cis stereochemistry at C-4/C-10 in lasubine II could be achieved by cis-stereoselective conjugate addition[8] of an appropriate bifunctional organometallic reagent to **1** and subsequent S_N2 cyclization (Scheme 1, pathway B). Alternatively, a change in the order of steps, that is, first intermolecular nitrogen alkylation, followed by trans-stereoselective radical-mediated cyclization,[9] would lead to lasubine I (pathway A).

In an earlier study we had developed a very efficient method for the enantioselective preparation of *N*-sulfonyl 2,3-dihydropyridones based on the Cu(I)/Fesulphos catalyzed enantioselective formal aza-Diels−Alder reaction between *N*-sulfonylaldimines and Danishefsky's diene. By using this methodology the reaction of the *N*-tosyl imine of 3,4-dimethoxybenzaldehyde (**2**) with Danishefsky's diene, at room temperature in CH_2Cl_2, in the presence of catalytic amounts of the Cu-Fesulphos bromo

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(7) García-Mancheño, O.; Gómez-Arrayás, R.; Carretero, J. C. *J. Am. Chem. Soc*. **2004**, *126*, 456−457.

(8) For cis-stereoselective Cu-catalyzed 1,4-addition of organometallic reagents to *N*-acyl 2,3-dihydro-4-pyridones, see: (a) Comins, D. L.; Brown, J. D. *Tetrahedron Lett.* **1986**, *27*, 4549−4552. (b) Comins, D. L.; LaMunyon, D. H. *Tetrahedron Lett.* **1989**, *30*, 5053−5056. (c) Comins, D. L.; Zeller, E. *Tetrahedron Lett.* **1991**, *32*, 5889−5892. (d) Comins, D. L.; Joseph, S. P.; Goehring, R. R. *J. Am. Chem. Soc*. **1994**, *116*, 4719−4728.

(9) As a related precedent, a trans-stereoselective radical cyclization of a chiral (η^6-arene)$Cr(CO)_3$ complex of a *N*-functionalized 2,3-dihydropyridone has been applied by Kündig et al. in their synthesis of (−)-lasubine I, see ref 5c.

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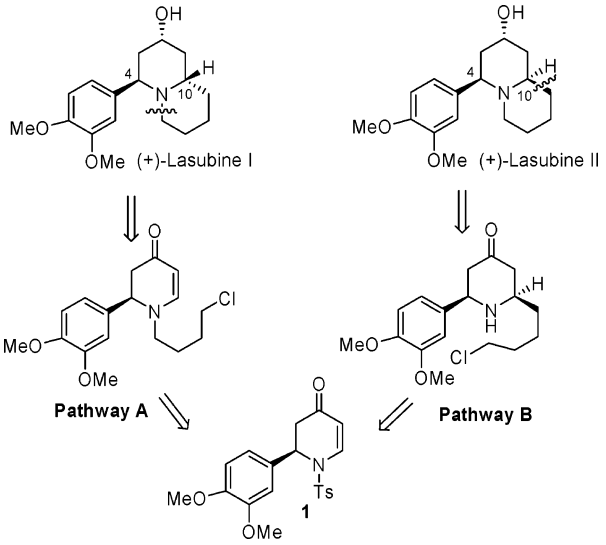
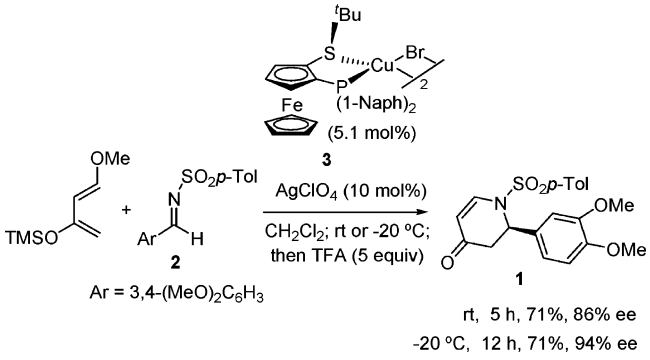
SCHEME 1. Retrosynthetic Analysis



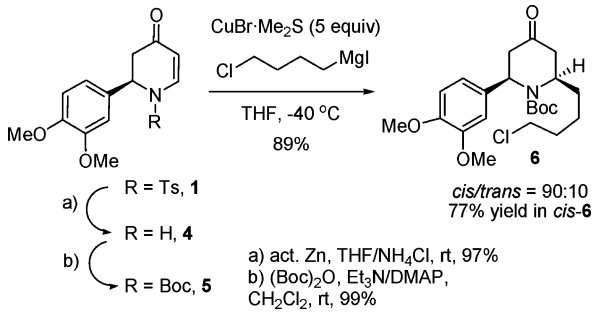
SCHEME 2. Enantioselective Synthesis of the Key Dihydropyridone 1



dimer complex **3** (5.1 mol %) and $AgClO_4$ (10 mol %), followed by addition of TFA,[10] afforded the dihydropyridone **1** in 71% yield and 86% ee. Interestingly, a higher enantioselectivity (94% ee), preserving a similar chemical yield, was obtained by performing the reaction at −20 °C (Scheme 2).

Having accomplished the key asymmetric process, the next step for the synthesis of lasubine II would be the stereoselective Cu-catalyzed conjugate addition of 4-chlorobutyl magnesium iodide to the pyridone **1**. However, the *N*-tosyl enone **1** proved to be a very poor substrate for this conjugate addition. In the best case, the addition product was obtained with very low yield (25%) and stereoselectivity (cis/trans = 70/30). Therefore, we decided to replace the tosyl group at nitrogen by a less bulky protecting group, such as a carbamate.[11] To this end it was essential to find an efficient method for the deprotection of the sulfonamide group in the presence of the enaminone moiety.[12]

SCHEME 3. Conjugate Addition to the Dihydropyridone 5



After some experimentation, we found that this deprotection can be cleanly achieved by reductive cleavage with activated powdered zinc[13] in a THF/saturated aqueous solution of NH_4Cl at room temperature, leading to the unprotected *N*-H pyridone **4** in 97% yield.[14] Compound **4** is highly crystalline and a single recystallization (acetone/pentane) of a 94% ee sample enhanced the optical purity to >99% ee (77% yield of the recrystallization). Its further protection as a Boc derivative under standard conditions provided the required *N*-Boc pyridone **5** in 99% yield (Scheme 3).

Pleasingly, the cuprate addition reaction of 4-chlorobutyl magnesium iodide (5 equiv) under Comins' conditions[12] ($CuBr\cdot Me_2S$ as copper source and $BF_3\cdot Et_2O$ as Lewis acid) provided the 1,4-addition product with high yield and stereoselectivity (cis/trans = 90/10). After standard chromatographic separation the required *cis*-2,6-disubstituted-piperidone **6** was obtained in 77% yield (Scheme 3).

Disappointingly, the further construction of the quinolizidine skeleton by Boc-deprotection under the usual conditions (TFA or HCl/AcOEt) and in situ intramolecular *N*-alkylation occurred with low yield (≤34% isolated yield), likely due to the competitive opening of the 4-piperidone unit under acid conditions.[15] To overcome this problem milder Boc-deprotection methods were tested. In particular, the cleavage of the Boc group of **6** was achieved in quantitative yield by using $SnCl_4$ in EtOAc.[16] The resulting *N*-H piperidone was then converted into the quinolizidine ketone[17] **7** by treatment of the resulting crude mixture with K_2CO_3 (70% overall yield). Finally, as previously reported in the synthesis of (−)-lasubine II by reduction of the enantiomer of **7**,[5b,6d] the fully stereoselective reduction of the carbonyl group with L-selectride provided (+)-lasubine II[18] (Scheme 4).

With regard to the enantioselective synthesis of (+)-lasubine I, as shown in the retrosynthetic analysis (Scheme 1), the trans configuration at C-4/C10 of the quinolizidine unit was expected to be achieved by stereoselective radical cyclization. Initial *N*-alkylation of the *N*-H dihydropyridone **4** with 4-chloro-1-

(10) In this formal aza-Diels−Alder protocol, the addition of TFA to the crude reaction mixture is required for the acid promoted cyclization of the open Mannich-type intermediate, which was obtained as the main product in the Cu-catalyzed condensation of *N*-tosylimine **2** with Danishefsky's diene.

(11) Brown, J. D.; Foley, M. A.; Comins, D. L. *J. Am. Chem. Soc.* **1988**, *110*, 7445−7447.

(12) To the best of our knowledge no examples of deprotection of *N*-sulfonyl-2,3-dihydro-4-pyridones have been reported. For classical methods for deprotection of sulfonamides, see: Greene, T. W.; Wuts, P. G. M. *Protective Groups in Organic Synthesis*, 3rd ed.; John Wiley & Sons: New York, 1999; pp 603−615.

(13) Holton, R. A.; Crouse, D. J.; Williams, A. D.; Kenedy, R. M. *J. Org. Chem.* **1987**, *52*, 2317−2318.

(14) For other Zn-mediated reductive desulfonylations, see for instance: (a) Holton, R. A.; Kenedy, R. M.; Kim, H.-B.; Krafft, M. E. *J. Am. Chem. Soc.* **1987**, *109*, 1597−1600. (b) Adrio, J.; Rodriguez-Rivero, M.; Carretero, J. C. *Angew. Chem., Int. Ed.* **2000**, *39*, 2906−2909.

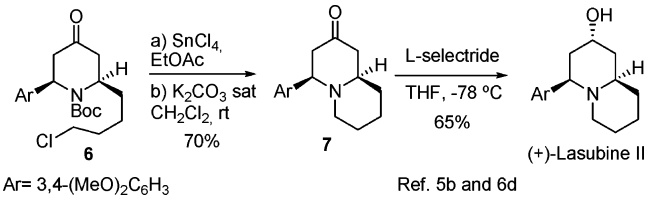
(15) Several side products, such as open enones and azetine derivatives, were detected after acid treatment of **6**.

(16) (a) Frank, R.; Schutkowski, M. *Chem. Commun.* **1996**, 2509−2510. (b) Miel, H.; Rault, S. *Tetrahedron Lett.* **1997**, *38*, 7865−7866.

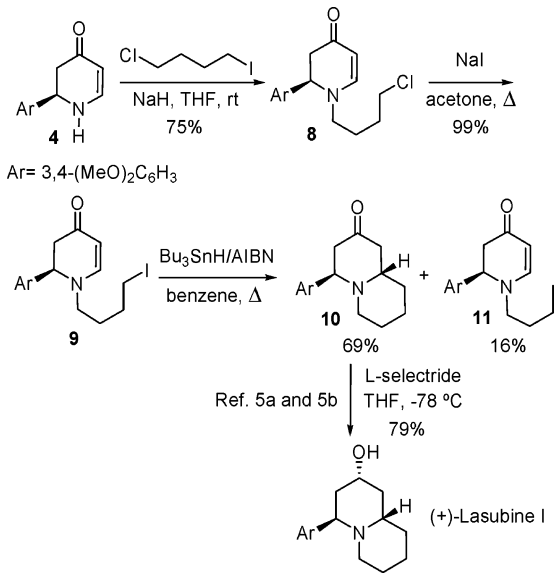
(17) The enantiomer of ketone **7** has been previously described; see refs 5b and 6d.

(18) $[\alpha]^{20}_D$ +50 (*c* 0.3, MeOH); lit. (−)-lasubine II $[\alpha]^{25}_D$ −50 (*c* 0.37, MeOH), see ref 6a; $[\alpha]^{25}_D$ −53 (*c* 0.13, MeOH), see ref 6d.

SCHEME 4. Stereoselective Synthesis of (+)-Lasubine II



SCHEME 5. Stereoselective Synthesis of (+)-Lasubine I



iodobutane (NaH, THF) provided the required *N*-functionalized chloro-derivative **8** in 75% yield (Scheme 5). However, all attempts to carry out the radical cyclization of this substrate under thermal (Bu_3SnH, AIBN, benzene, reflux) or photochemical (Bu_3SnH, Hg, 120 V, 400 nm, 35 °C) conditions[19] failed, leading to only traces of the quinolizidine derivative. To improve the reactivity of the radical precursor, the iodo derivative **9** was prepared in almost quantitative yield by reaction of **8** with NaI in acetone. The treatment of the iodo derivative **9** under standard radical cyclization conditions (Bu_3SnH, AIBN, benzene, reflux) yielded the quinolizidine ketone **10**,[20] exclusively as the trans isomer (69%), along with a minor amount of the noncyclized reduction product **11** (16%). Finally, as previously reported,[5a,b] the stereoselective carbonyl reduction of **10** with L-selectride afforded (+)-lasubine I in good yield[21] (Scheme 5).

In conclusion, we have developed a concise, stereodivergent, and highly stereoselective synthesis of (+)-lasubines I and II from a common enantiopure *N*-tosyl 2,3-dihydropyridone. This key intermediate was obtained by applying a novel Cu-catalyzed asymmetric aza-Diels−Alder protocol between *N*-tosyl imines and Danishefsky's diene.

Experimental Section

The quinolizidine ketones **7** and **10** and lasubines I and II have been previously described in the literature. See the Supporting Information for experimental procedures and characterization data.

(*R*)-2,3-Dihydro-2-(3,4-dimethoxyphenyl)-1-(4-tolylsulfonyl)-pyridin-4(*1H*)-one (1): A solution of **3** (70.9 mg, 0.056 mmol) and $AgClO_4$ (23 mg, 0.11 mmol) in CH_2Cl_2 (6 mL) was stirred in the dark at room temperature under argon for 2 h then treated with a solution of imine **2** (350 mg, 1.10 mmol) in CH_2Cl_2 (10 mL). The reaction mixture was stirred at room temperature for 5 min and cooled to −20 °C before it was treated with Danishefsky's diene (300 μL, 1.50 mmol) and stirred at −20 °C for 12 h. TFA (1 mL) was added and the mixture was stirred at room temperature for an additional 30−60 min. The reaction mixture was neutralized with saturated aqueous $NaHCO_3$, extracted with CH_2Cl_2, dried over $MgSO_4$, and filtered. After evaporation of the solvent, the residue was purified by flash chromatography (EtOAc/hexane 4:1) to afford **1** (302 mg, 71%, 94% ee, pale yellow solid). Mp: 52−54 °C (Et_2O). $[\alpha]^{20}_D$ +29 (*c* 0.24, $CHCl_3$), >99% ee. HPLC: Daicel Chiralcel OD, *n*-hexane/*i*-PrOH 70:30, flow 0.8 mL/min, 290 nm, (*S*)-**1** t_R = 18.4 min, (*R*)-**1** t_R = 30.0 min. ^{1}H NMR (300 MHz): δ 7.75 (dd, 1H, *J* = 8.3, 1.4 Hz, H-6), 7.58 (d, 2H, *J* = 8.5 Hz, Ar), 7.22 (d, 2H, *J* = 8.5 Hz, Ar), 6.75−6.60 (m, 3H, Ar), 5.46 (d, 1H, *J* = 6.9 Hz, H-2), 5.40 (d, 2H, *J* = 8.3 Hz, H-5), 3.80 (s, 3H, CH_3O), 3.76 (s, 3H, CH_3O), 2.79 (dd, 1H, *J* = 16.6, 6.9 Hz, CH_2), 2.64 (d, 1H, *J* = 16.6 Hz, CH_2), 2.38 (s, 3H, CH_3). ^{13}C NMR (75 MHz): δ 190.8, 149.0, 148.9, 144.9, 142.3, 135.7, 129.9, 129.4, 127.0, 118.9, 110.8, 109.6, 108.1, 57.4, 55.8, 55.6, 41.6, 21.5. IR (CH_2Cl_2): ν 2937, 1672, 1597, 1519, 1268, 1169, 1053. MS (EI+): 387 (M^+, 57), 232 (M^+ − Ts, 36), 164 (100), 91 (45). HRMS (EI+) calcd for $C_{20}H_{21}NO_5S$ 387.1140, found 387.1131.

(*R*)-2,3-Dihydro-2-(3,4-dimethoxyphenyl)pyridin-4(*1H*)-one (4): To a suspension of **1** (350 mg, 0.90 mmol) of 94% ee and activated zinc dust (1.30 g, 20 mmol) in THF (5 mL) was added a saturated aqueous solution of NH_4Cl (5 mL). The mixture was stirred at room temperature for 24 h, diluted with a 1:1 AcOEt/hexane mixture, and filtered through Celite. The organic layer was separated and concentrated under reduced pressure to afford **4** (203 mg, 97%, pale yellow solid). Recrystallization from acetone/pentane gave **4** with >99% ee (156 mg, 77%). Mp: 164−165 °C (acetone/pentane). $[\alpha]^{20}_D$ −110 (*c* 0.05, acetone), >99% ee. HPLC: Daicel Chiralcel OD, *n*-hexane/*i*-PrOH 70:30, flow 0.8 mL/min, 310 nm, (*S*)-**4** t_R = 13.6 min, (*R*)-**4** t_R = 22.9 min. ^{1}H NMR (CD_2Cl_2, 300 MHz): δ 7.25 (t, 1H, *J* = 7.0 Hz, Ar), 6.95−6.82 (m, 3H, Ar + H-6), 5.08 (s ancho, 1H, NH), 5.00 (d, 1H, *J* = 7.5 Hz, H-5), 4.66 (dd, 1H, *J* = 14.8, 4.8 Hz, H-2), 3.82 (s, 3H, CH_3O), 3.80 (s, 3H, CH_3O), 2.68 (dd, 1H, *J* = 16.2, 14.8 Hz, CH_2), 2.43 (ddt, 1H, *J* = 16.2, 4.8, 1.2 Hz, CH_2). ^{13}C NMR (CD_2Cl_2, 75 MHz): δ 191.8, 150.8, 149.5, 149.3, 132.8, 118.8, 111.6, 110.0, 99.4, 58.4, 55.9, 45.0. IR (KBr): ν 3224, 3046, 1611, 1572, 1538, 1514, 1253, 1134. MS (EI+): 233 (M^+, 94), 164 (100). HRMS (EI+) calcd for $C_{13}H_{15}NO_3$ 233.1052, found 233.1054.

(*R*)-1-(*tert*-Butoxycarbonyl)-2,3-dihydro-2-(3,4-dimethoxyphenyl)pyridin-4(*1H*)-one (5): To a solution of **4** (100 mg, 0.43 mmol, >99% ee), Et_3N (148 μL, 1.07 mmol), and DMAP (5.0 mg) in CH_2Cl_2 (8 mL) was added $(Boc)_2O$ (234.0 mg, 1.07 mmol). The mixture was stirred at room temperature for 6 h and a saturated aqueous solution of NH_4Cl (5 mL) was added. The organic layer was separated and the aqueous phase was extracted with CH_2Cl_2 (10 mL). The combined organic phase was washed with brine, dried over $MgSO_4$, and filtered. After evaporation of the solvent, the residue was purified by flash chromatography (AcOEt/hexane 1:4) to afford **5** (141.7 mg, 99%, pale yellow solid). Mp: 91−93 °C. $[\alpha]^{20}_D$ −143 (*c* 0.30, $CHCl_3$). ^{1}H NMR (200 MHz): δ 7.85 (d, 1H, *J* = 8.3 Hz, H-6), 6.80−6.64 (m, 3H, Ar), 5.58 (d, 1H, *J* = 7.5 Hz, H-2), 5.26 (d, 1H, *J* = 8.3 Hz, H-5), 3.70 (s, 3H, CH_3O), 3.68 (s, 3H, CH_3O), 3.06 (dd, 1H, *J* = 16.4, 7.5 Hz, CH_2), 2.71 (d, 1H, *J* = 16.4 Hz, CH_2), 1.41 (s, 9H, *t*-Bu). ^{13}C NMR (50 MHz): δ 192.2, 151.3, 149.0, 148.5, 142.5, 131.3, 118.1, 110.9, 109.3, 106.6, 83.5, 55.6, 55.0, 41.5, 27.8. IR (CH_2Cl_2): ν 3057, 2983, 1724, 1668, 1605, 1518, 1266, 1151. MS (EI+): 333 (M^+, 31),

(19) For a review on intramolecular 1,4-radical cyclizations, see: Zhang, W. *Tetrahedron* **2001**, *57*, 7237−7262.

(20) The enantiomer of ketone **10** has been previously described; see refs 5a and 5b.

(21) $[\alpha]^{25}_D$ +6.2 (*c* 0.34, MeOH); lit. (−)-lasubine I $[\alpha]^{25}_D$ −6.5 (*c* 2.60, MeOH), see ref 5b; $[\alpha]^{25}_D$ −7.0 (*c* 0.37, MeOH), see ref 5c.

277 (28), 233 (35), 164 (45), 57 (100). HRMS (EI+) calcd for $C_{18}H_{23}NO_5$ 333.1576, found 333.1576.

(2*R*,6*R*)-1-(*tert*-Butoxycarbonyl)-6-(4-chlorobutyl)-2-(3,4-dimethoxyphenyl)piperidin-4-one (*cis*-6): To a suspension of CuBr·Me_2S (296 mg, 1.44 mmol) in THF (5 mL), cooled to −78 °C, was added a 1 M solution of Cl-$(CH_2)_4$-MgI in Et_2O (2.9 mL, 2.88 mmol). The resulting mixture was stirred for 5 min at −78 °C and BF_3·Et_2O (684 μL, 5.40 mmol) and a solution of **5** (120 mg, 0.36 mmol) in THF (5 mL) were successively added. The reaction was stirred at −78 °C for 20 h and a saturated aqueous solution of NH_4Cl (5 mL) and a 30% aqueous solution of NH_4OH (0.8 mL) were added. The organic layer was separated and the aqueous phase was extracted with CH_2Cl_2 (10 mL). The combined organic phase was washed with brine, dried over $MgSO_4$, and filtered. After evaporation of the solvent, the residue (90:10 cis−trans mixture) was purified by flash chromatography (AcOEt/hexane 1:4) to afford *cis*-**6** (118 mg, 77%, colorless oil). $[\alpha]^{20}_D$ +64 (*c* 0.40, $CHCl_3$). ^{1}H NMR (300 MHz): δ 6.99−6.92 (m, 1H, Ar), 6.86 (dd, 1H, J = 8.3, 2.0 Hz, Ar), 6.76 (d, 1H, J = 8.3 Hz, Ar), 5.90−5.70 (m, 1H, H-2), 4.70−4.50 (m, 1H, H-6), 3.85 (s, 3H, CH_3O), 3.83 (s, 3H, CH_3O), 3.32 (t, 2H, J = 6.2 Hz, CH_2), 2.98 (dd, 1H, J = 15.8, 3.6 Hz, CH_2), 2.80 (dd, 1H, J = 16.2, 7.3 Hz, CH_2), 2.71 (dd, 1H, J = 15.4, 7.3 Hz, CH_2), 2.30 (dd, 1H, J = 15.4, 2.8 Hz, CH_2), 1.65−1.05 (m, 6H, $3CH_2$), 1.50 (s, 9H, *t*-Bu). ^{13}C NMR (75 MHz): δ 207.9, 155.4, 148.7, 148.1, 135.4, 118.3, 110.7, 110.2, 80.6, 55.8, 55.6, 52.5, 44.6, 44.4, 43.4, 35.3, 31.8, 28.2, 23.9. IR ($CDCl_3$): ν 2937, 1719, 1683, 1518, 1254. MS (EI+): 425 (M^+, 11), 369 (84), 335 (52), 191 (82), 164 (53), 57 (100). HRMS (EI+) calcd for $C_{22}H_{32}ClNO_5$ 425.1969, found 425.1961.

(*R*)-1-(4-Chlorobutyl)-2,3-dihydro-2-(3,4-dimethoxyphenyl)-pyridin-4(*1H*)-one (8): To a solution of **4** (47.0 mg, 0.20 mmol) in THF (10 mL) was added NaH 60% in mineral oil (22.0 mg, 0.54 mmol) at room temperature. The mixture was stirred at room temperature for 5 min and 4-chloro-1-iodobutane (50 μL, 0.40 mmol) was added. The reaction was stirred for 18 h followed by addition of water (5 mL). The organic phase was separated and the aqueous phase was extracted with CH_2Cl_2 (10 mL). The combined organic phase was washed with brine, dried over $MgSO_4$, and filtered. After evaporation of the solvent, the residue was purified by flash chromatography (AcOEt) to afford **8** (48 mg, 75%, pale yellow oil). $[\alpha]^{20}_D$ −113 (*c* 0.20, $CHCl_3$). ^{1}H NMR (300 MHz): δ 7.10 (d, 1H, J = 7.7 Hz, H-6), 6.80 (s, 3H, Ar), 4.95 (d, 1H, J = 7.7 Hz, H-5), 4.52 (dd, 1H, J = 8.9, 6.9 Hz, H-2), 3.82 (s, 6H, $2CH_3O$), 3.50−3.39 (m, 2H, CH_2), 3.14−2.95 (m, 2H, CH_2), 2.78 (dd, 1H, J = 16.4, 6.9 Hz, CH_2), 2.62 (dd, 1H, J = 16.4, 8.9 Hz, CH_2), 1.78−1.53 (m, 4H, $2CH_2$). ^{13}C NMR (50 MHz): δ 190.3, 153.8, 149.3, 149.0, 131.0, 119.4, 111.2, 109.8, 98.3, 60.8, 55.8, 52.4, 44.1, 43.9, 29.3, 25.8. IR (CH_2Cl_2): ν 2926, 1634, 1580, 1516, 1262. MS (FAB+): 324 (M^+ + H, 100), 154 (71). HRMS (FAB+) calcd for $C_{17}H_{23}ClNO_3$ 324.1366, found 324.1364.

(*R*)-2,3-Dihydro-1-(4-iodobutyl)-2-(3,4-dimethoxyphenyl)pyridin-4(*1H*)-one (9): To a solution of **8** (45.0 mg, 0.14 mmol) in acetone (1.5 mL) was added NaI (209.3 mg, 1.40 mmol) and the resulting solution was refluxed for 15 h. The reaction was cooled to room temperature, the solvent was evaporated at reduced pressure, and a 1:1 mixture of Et_2O/H_2O (4 mL) was added. The organic layer was separated and the aqueous phase was extracted with CH_2Cl_2 (10 mL). The combined organic phase was washed with brine, dried over $MgSO_4$, filtered, and evaporated to afford **9** (57.5 mg, 99%, pale yellow oil), which was used without further purification in the next reaction step. $[\alpha]^{20}_D$ −90 (*c* 0.30, $CHCl_3$). ^{1}H NMR (300 MHz): δ 7.11 (d, 1H, J = 7.7 Hz, H-6), 6.87−6.78 (m, 3H, Ar), 5.01 (d, 1H, J = 7.7 Hz, H-5), 4.43 (dd, 1H, J = 9.1, 6.7 Hz, H-2), 3.85 (s, 6H, $2CH_3O$), 3.18−2.98 (m, 4H, $2CH_2$), 2.79 (dd, 1H, J = 16.4, 6.7 Hz, CH_2), 2.67 (dd, 1H, J = 16.4, 9.1 Hz, CH_2), 1.85−1.55 (m, 4H, $2CH_2$). ^{13}C NMR (50 MHz): δ 190.4, 153.8, 149.4, 149.0, 131.0, 119.5, 111.3, 109.8, 98.5, 61.0, 56.0, 55.9, 52.1, 44.0, 30.1, 29.4. IR (CH_2Cl_2): ν 2925, 1620, 1570, 1516, 1262. MS (FAB+): 416 (M^+ + H, 12), 306 (46), 154 (68), 55 (100). HRMS (FAB+) calcd for $C_{17}H_{23}INO_3$ 416.0723, found 416.0739.

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Supporting Information Available: Copies of NMR spectra, experimental procedures, and characterization data for previously reported compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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