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Concise Asymmetric Formal Synthesis of Pyrrolopiperazinone Natural Products by Tandem Cross Metathesis/Intramolecular Aza-Conjugate Addition

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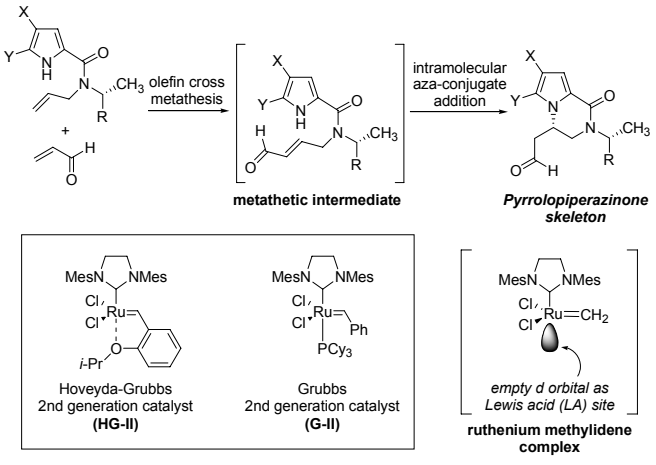
With the advent of air-stable, commercially available, and functional group-tolerable ruthenium-carbene catalysts, olefin metathesis has become a powerful tool for carbon-carbon double bond formations, with various applications reported over the past decade.[1] Meanwhile, tandem reactions, which involve ruthenium-catalyzed olefin metathesis followed by other transformations, have also been reported, giving non-metathetic products.[2] These tandem reactions broaden the synthetic utility of metathesis-active ruthenium-carbene catalysts beyond olefin metathesis, and provide an important tool for the rapid and efficient synthesis of complex molecules from simple starting materials. Recent examples include ring-closing metathesis (RCM) with Kharasch addition,[3] olefin isomerization,[4] oxidation process,[5] and hydrogenation;[6] cross metathesis (CM) with intramolecular aza-Michael reaction,[7] intramolecular oxa-conjugate cyclization,[8] and intramolecular hydroarylation;[9] and ring-closing enyne metathesis (RCEYM) with cyclopropanation,[10] metallotropic [1,3]-shift,[11] and hydrovinylation.[12] In these tandem reactions, the use of *N*-centered heteroaromatic nucleophiles remains unexplored, in contrast to the reported use of an *N*-centered aliphatic nucleophile in the tandem CM/intramolecular aza-Michael reaction,[7] in spite of the importance of optically pure *N*-heteroaromatic compounds as pharmacophores in biologically active natural products.[13] Therefore, we planned an asymmetric formal synthesis of pyrrolopiperazinone natural product *via* the development of stereoselective tandem CM/intramolecular aza-conjugate addition reactions using pyrrole as the first use of the *N*-centered heteroaromatic nucleophile in the metathesis-active ruthenium-catalyzed tandem reactions (Scheme 1). Moreover, it was supposed that the tandem reaction would be performed by the sequential activation of the metathetic intermediate with an active ruthenium species as a Lewis acid, e.g., a ruthenium methylidene complex[7,10] generated from the initiation of the CM process, or a ruthenium hydride species[8,14] generated from the decomposition of the ruthenium methylidene complex under high temperature conditions.



Scheme 1. Concept of metathesis-active ruthenium-catalyzed diastereoselective tandem reaction for the formation of pyrrolopiperazinone skeleton

Pyrrolopiperazinone is one of the key skeletons found in pyrrole alkaloids, which are a class of marine natural products with a variety of potent biological activities.[15] Examples of pyrrolopiperazinone natural products include hanishin,[16] longamide B,[17] longamide B methyl ester,[18] cyclooroidin,[19] and the agesamides[20] (Figure 1). They were isolated from sponge *Agelas* species, except for hanishin, which came from *Acanthella* species, and exhibit interesting biological properties such as cytotoxic activity and antibiotic activity. Although these pyrrolopiperazinone natural products have considerable biological activities and chemical skeletons, and thus are potentially useful for the development of pharmaceuticals, few reports on the asymmetric syntheses of the above pyrrolopiperazinone natural products are available. The only reports involve synthetic routes using Pd-catalyzed asymmetric annulation[21] and chiral pool[22] for the asymmetric synthesis of the pyrrolopiperazinone natural products.[23] Therefore, the development of a new route for the asymmetric synthesis of the pyrrolopiperazinone natural products is highly desirable. Herein, we report the concise asymmetric formal synthesis of the pyrrolopiperazinone natural products *via* the diastereoselective tandem CM/intramolecular aza-conjugate addition of acrolein to substrates **3** having pyrrole as the *N*-centered heteroaromatic nucleophile (Scheme 2).

To explore the feasibility of using the diastereoselective

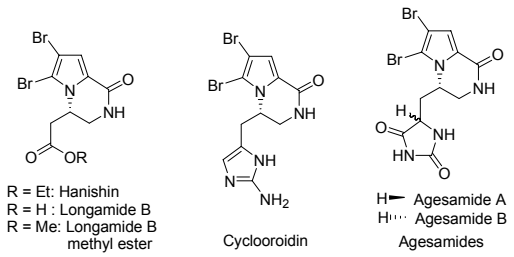
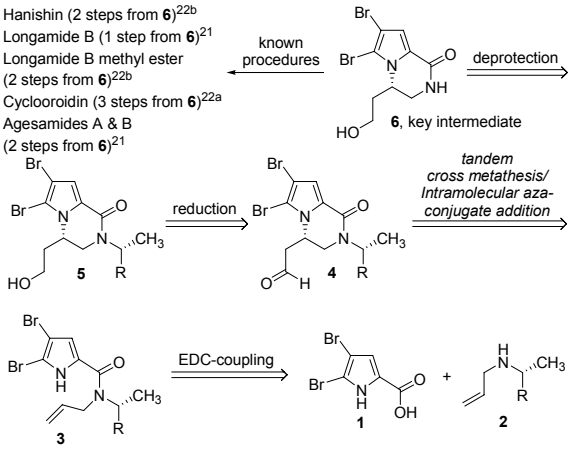
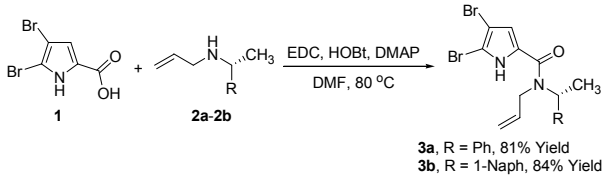


Figure 1. Pyrrolopiperazinone natural products



Scheme 2. Retrosynthetic analysis for asymmetric formal synthesis of pyrrolopiperazinone natural products

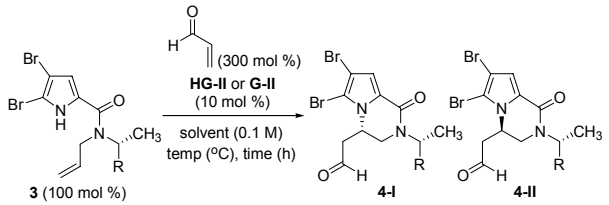


Scheme 3. Preparation of substrates **3a** and **3b**

metathesis-active ruthenium-catalyzed tandem CM/intramolecular aza-conjugate addition as the key reaction for the asymmetric formal synthesis of the pyrrolopiperazinone natural products, we first prepared substrates **3** bearing (*R*)-1-arylethyl groups as a chiral auxiliary to control the asymmetric induction in the tandem reactions (Scheme 3). The substrates **3a** and **3b** were obtained by amide bond forming reactions of commercially available 4,5-dibromo-1*H*-pyrrole-2-carboxylic acid (**1**) with a series of (*R*)-*N*-allyl-1-arylethylamines **2a** and **2b** using EDC·HCl-DMAP as coupling reagents and HOBt as a deracemization additive. Good yields were obtained without any racemization, as determined by chiral HPLC analysis (Chiralcel OD-H) with a racemic standard.

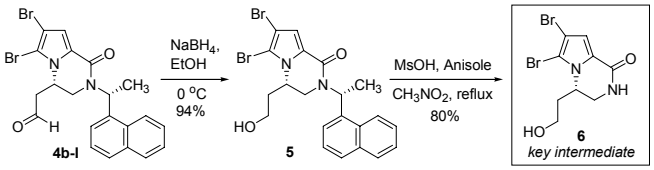
With the substrates **3a** and **3b** prepared, the diastereoselective tandem CM/intramolecular aza-conjugate addition reactions of acrolein to the substrates **3** using Hoveyda-Grubbs 2nd generation catalyst (**HG-II**) in dichloromethane at ambient temperature were carried out (Table 1, entries 1-2). Among the substrates **3a** and **3b** tested, gratifyingly, substrate **3b**, bearing the bulkier chiral (*R*)-1-(1-naphthyl)ethyl group as the chiral auxiliary, provided the corresponding tandem product **4b** in 55% yield as a 2.3:1 mixture of diastereomers, without the metathetic intermediate. When **HG-II** was replaced with Grubbs 2nd generation catalyst (**G-II**) at 40 °C, with the other reaction conditions remaining the same, the tandem product **4b** was obtained with a decreased yield of 32% and diastereomeric ratio of 1.3:1 (Table 1, entry 3 *vs*. entry 2). Hence, **HG-II** proved superior. By varying the reaction temperature to increase the yield and the diastereomeric ratio of the tandem reaction, ambient temperature was identified as the ideal temperature for the tandem reaction (Table 1, entry 4 *vs*. entry 2). Then, using a portionwise addition method for **HG-II** (Table 1, entries 5-6), indeed, when

Table 1. Optimization of diastereoselective tandem CM/intramolecular aza-conjugate addition reactions of acrolein to substrates **3**[a]



Entry	R	Catalyst	Solvent	Temp. (°C)	Time (h)	Yield (%)	Dr[b] [**4-I**:**4-II**]
1	Ph (**3a**)	**HG-II**	CH_2Cl_2	rt	4	34 (**4a**)	2.5:1
2	1-Naph (**3b**)	**HG-II**	CH_2Cl_2	rt	4	55 (**4b**)	2.3:1
3	1-Naph (**3b**)	**G-II**	CH_2Cl_2	40	2	32 (**4b**)	1.3:1
4[c]	1-Naph (**3b**)	**HG-II**	$ClCH_2CH_2Cl$	80	2	14 (**4b**)	-[d]
5	1-Naph (**3b**)	**HG-II**[e]	CH_2Cl_2	rt	3	54 (**4b**)	2.6:1
6	**1-Naph (3b)**	**HG-II**[f]	**CH_2Cl_2**	**rt**	**4**	**56 (4b)**	**3.3:1**
7	1-Naph (**3b**)	**HG-II**[f]	CH_2Cl_2	rt	6	49 (**4b**)	3.3:1

[a]Procedure: To a solution of substrate **3** (0.3 mmol, 100 mol %) and catalyst (0.03 mmol, 10 mol %) in CH_2Cl_2 (3 mL, 0.1 M) was added acrolein (0.9 mmol, 300 mol %). The reaction mixture was stirred at rt, 40 °C, or 80 °C, until the substrate was no longer consumed, at which point the reaction mixture was evaporated onto silica gel and the product was isolated by silica gel chromatography. [b]Dr was determined by isolated yields of two diastereomers. [c]Crotonaldehyde instead of acrolein was used. [d]Not determined. [e]Two 5 mol % additions of **HG-II** were used, with an interval of one hour. [f]Two 5 mol % additions of **HG-II** were used, with an interval of two hours.



Scheme 4. Formal synthesis of key intermediate **6** in synthesis of pyrrolopiperazinone natural products

the two 5 mol % additions of **HG-II** were carried out at an interval of two hours in the tandem reaction, the tandem product **4b** was obtained in 56% yield and an increased diastereomeric ratio of 3.3:1 (Table 1, entry 6). In cases where the reaction with the intervals of two hours for the **HG-II** additions was carried out longer than four hours, no further increase in the yield of **4b** was obtained (Table 1, entry 7).

To complete the asymmetric formal synthesis of the pyrrolopiperazinone natural products, reduction of the tandem product **4b-I** was performed with sodium borohydride in ethanol at 0 °C, affording the alcohol **5** in 94% yield (Scheme 4). Finally, the removal of the (*R*)-1-(1-naphthyl)ethyl group of **5** with methanesulfonic acid and anisole in nitromethane at reflux provided the useful intermediate **6** in the synthesis of the pyrrolopiperazinone natural products, as reported earlier, in 80% yield. The spectroscopic and analytical data for **6** were in full agreement with those reported.[21,22b] The pyrrolopiperazine natural products such as hanishin,[22b] longamide B,[21] longamide B methyl ester,[22b] cyclooroidin,[22a] and the agesamides[21] can be synthesized from the intermediate **6** in a few steps according to procedures found in the literature.

In summary, we achieved the concise asymmetric formal synthesis of the pyrrolopiperazinone natural products, *via* the

diastereoselective tandem CM/intramolecular aza-conjugate addition reaction, from 4,5-dibromo-1*H*-pyrrole-2-carboxylic acid (**1**) to the key intermediate **6** in only four linear steps. The tandem reaction of substrate **3b**, bearing the (*R*)-1-(1-naphthyl)ethyl group as the chiral auxiliary, was performed using **HG-II** as a single species to carry out the sequential reaction, affording a 56% yield of the non-metathetic product, pyrrolopiperazinone **4b**, as a 3.3:1 mixture of diastereomers. In addition, this is the first example of pyrroles as an *N*-centered heteroaromatic nucleophile in the metathesis-active ruthenium-catalyzed tandem reactions. Future studies will be devoted to the development of new metathesis-active ruthenium-catalyzed tandem reactions and their application to the synthesis of biologically active natural products.

Experimental Section

General Procedure for the Synthesis of Substrates 3a and 3b. To a stirred solution of 4,5-dibromo-1*H*-pyrrole-2-carboxylic acid (**1**, 2.84 g, 10.59 mmol), (*R*)-*N*-allyl-1-arylethylamine **2** (3.53 mmol), 1-hydroxybenzotriazole (1.43 g, 10.59 mmol), and 4-DMAP (1.29 g, 10.59 mmol) in DMF (12 mL) was added *N*-(3-dimethylaminopropyl)-*N*′-ethylcarbodiimide hydrochloride (2.03 g, 10.59 mmol) at ambient temperature. The mixture was heated to 80 °C and stirred for 12 h. The mixture was quenched with 1.0 M HCl solution and extracted with Et_2O. The combined ether layers were washed with saturated $NaHCO_3$ followed by brine, and dried over Na_2SO_4. The solvent was evaporated in vacuo to give the crude product.

(*R*)-*N*-Allyl-4,5-dibromo-*N*-(1-phenylethyl)-1*H*-pyrrole-2-carboxamide (3a). Prepared by the general procedure from (*R*)-*N*-(1-phenylethyl)prop-2-en-1-amine (**2a**, 0.569 g, 3.53 mmol). The crude product was purified by flash chromatography (SiO_2, 5% EtOAc/hexanes) to give the substrate **3a** as a light brown oil (1.17 g, 81%): $[\alpha]_D^{20}$ +63.5 (*c* 1, CH_3OH); ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.57 (s, 1H), 7.35-7.25 (m, 5H), 6.60 (d, *J* = 3.2 Hz, 1H), 6.20-6.15 (m, 1H), 5.87-5.75 (m, 1H), 5.10-5.06 (m, 2H), 4.21 (d, *J* = 16.8 Hz, 1H), 3.82-3.67 (m, 1H), 1.65 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.1, 140.0, 134.7, 128.5, 127.5, 127.3, 125.8, 116.7, 115.5, 105.9, 99.5, 53.5, 46.5, 17.5; IR (neat) 3168, 2925, 1588, 1451, 1412, 1240, 1177, 976, 751, 698 cm^{-1}; HRMS calcd for [M] $C_{16}H_{16}Br_2N_2O$ 409.9629, found 409.9626.

(*R*)-*N*-Allyl-4,5-dibromo-*N*-(1-(naphthalen-1-yl)ethyl)-1*H*-pyrrole-2-carboxamide (3b). Prepared by the general procedure from (*R*)-*N*-(1-(naphthalene-1-yl)ethyl)prop-2-en-1-amine (**2b**, 0.745 g, 3.53 mmol). The crude product was purified by flash chromatography (SiO_2, 5% EtOAc/hexanes) to give the substrate **3b** as a light yellow solid (1.37 g, 84%): mp 79 - 81 °C; $[\alpha]_D^{20}$ +31.4 (*c* 1, CH_3OH); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.66 (s, 1H), 8.05-7.95 (m, 1H), 7.86-7.82 (m, 2H), 7.59-7.57 (m, 1H), 7.49-7.46 (m, 3H), 6.82 (s, 1H), 6.55-6.45 (m, 1H), 5.32-5.21 (m, 1H), 4.70-4.64 (m, 2H), 3.98-3.81 (m, 2H), 1.75 (d, *J* = 5.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.4, 135.1, 134.2, 133.6, 132.3, 129.0, 128.6, 126.9, 125.9, 125.1, 124.8, 123.6, 116.2, 115.7, 106.1, 99.6, 49.8, 46.2, 16.9; IR (neat) 3169, 2929, 1580, 1458, 1413, 1236, 1177, 975, 780 cm^{-1}; HRMS calcd for [M] $C_{20}H_{18}Br_2N_2O$ 459.9786, found 459.9785.

2-((*S*)-6,7-Dibromo-1-oxo-2-((*R*)-1-phenylethyl)-1,2,3,4-tetrahydropyrrolo[1,2-*a*]pyrazin-4-yl)acetaldehyde (4a). Dichloromethane (2 mL, 0.1 M), acrolein (40 μL, 0.6 mmol) and Hoveyda-Grubbs 2nd generation catalyst (12.5 mg, 0.02 mmol) were added to a 10 mL round-bottomed flask charged with (*R*)-*N*-allyl-4,5-dibromo-*N*-(1-phenylethyl)-1*H*-pyrrole-2-carboxamide (**3a**, 82 mg, 0.2 mmol) at room temperature and the mixture was stirred for 4 hours. After that time, the solution was concentrated to dryness and purified by flash chromatography (SiO_2, 20% EtOAc/hexanes) to provide **4a-I** as major diastereomer in 24% yield (21 mg, a light brown solid), and **4a-II** as minor diastereomer in 10% yield (9 mg, a yellow solid), respectively (total yield: 34%):

4a-I as Major Diastereomer: mp 118 - 119 °C; $[\alpha]_D^{20}$ −221.9 (*c* 1.15, CH_3OH); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.79 (s, 1H), 7.35-7.26 (m, 5H), 7.02 (s, 1H), 6.16 (q, *J* = 7.2 Hz, 1H), 4.75-4.73 (m, 1H), 3.40-3.30 (m, 2H), 3.04 (dd, *J* = 18.8, 10.4 Hz, 1H), 2.75 (dd, *J* = 17.6, 1.2 Hz, 1H), 1.48 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.1, 157.1, 138.8, 128.6, 127.8, 127.2, 125.4, 116.3, 105.0, 101.1, 48.8, 48.3, 44.7, 43.2, 16.0; IR (neat) 2926, 1720, 1640, 1426, 1329, 1129, 967, 700 cm^{-1}; HRMS calcd for [M] $C_{17}H_{16}Br_2N_2O$ 437.9579, found 437.9580:

4a-II as Minor Diastereomer: mp 71 - 73 °C; $[\alpha]_D^{20}$ −207.6 (*c* 1.1, CH_3OH); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.87 (s, 1H), 7.38-7.26 (m, 5H), 7.02 (s, 1H), 6.11 (q, *J* = 7.2 Hz, 1H), 4.63-4.59 (m, 1H), 3.74 (ddd, *J* = 13.2, 4.0, 1.2 Hz, 1H), 3.29 (dd, *J* = 13.2, 1.2 Hz, 1H), 2.39-2.31 (m, 2H), 1.53 (d, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.1, 156.7, 139.7, 128.7, 128.1, 127.8, 125.4, 116.1, 105.0, 100.9, 49.4, 48.0, 44.1, 41.8, 14.4; IR (neat) 2923, 1625, 1429, 1330, 1129, 968, 700 cm^{-1}; HRMS calcd for [M] $C_{17}H_{16}Br_2N_2O$ 437.9579, found 437.9576.

2-((*S*)-6,7-Dibromo-2-((*R*)-1-(naphthalene-1-yl)ethyl)-1-oxo-1,2,3,4-tetrahydropyrrolo[1,2-*a*]pyrazin-4-yl)acetaldehyde (4b). Dichloromethane (2 mL, 0.1 M), acrolein (40 μL, 0.6 mmol) and Hoveyda-Grubbs 2nd generation catalyst (6.25 mg, 0.01 mmol) were added to a 10 mL round-bottomed flask charged with (*R*)-*N*-allyl-4,5-dibromo-*N*-(1-(naphthalen-1-yl) ethyl)-1*H*-pyrrole-2-carboxamide (**3b**, 98 mg, 0.2 mmol) at room temperature and the mixture was stirred for 2 hours. At this point of time, additional Hoveyda-Grubbs 2nd generation catalyst (6.25 mg, 0.01 mmol) was added in the reaction mixture and the mixture was continuously stirred for 2 hours. After that time, the solution was concentrated to dryness and purified by flash chromatography (SiO_2, 20% EtOAc/hexanes) to provide **4b-I** as major diastereomer in 43% yield (42 mg, a yellow solid), and **4b-II** as minor diastereomer in 13% yield (13 mg, a brown solid), respectively (total yield: 56%):

4b-I as Major Diastereomer: mp 101 - 103 °C; $[\alpha]_D^{20}$ −20.1 (*c* 1, CH_3OH); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.79 (s, 1H), 8.10 (d, *J* = 8.0 Hz, 1H), 7.86-7.82 (m, 2H), 7.54-7.46 (m, 4H), 7.07 (s, 1H), 6.71 (q, *J* = 6.8 Hz, 1H), 4.61-4.58 (m, 1H), 3.28 (dd, *J* = 14.4, 1.6 Hz, 1H), 2.99 (dd, *J* = 18.8, 10.8 Hz, 1H), 2.87 (ddd, *J* = 14.4, 4.0, 1.6 Hz, 1H), 2.75-2.70 (m, 1H), 1.64 (d, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.0, 156.2, 134.1, 133.7, 131.6, 129.2, 128.7, 127.3, 126.1, 125.4, 125.0, 124.9, 123.4, 116.3, 104.9, 101.2, 48.2, 46.4, 45.0, 43.3, 17.2; IR (neat) 2924, 1725, 1629, 1427, 1330, 1129, 780 cm^{-1}; HRMS calcd for [M] $C_{21}H_{18}Br_2N_2O_2$ 487.9735, found 487.9733:

4b-II as Minor Diastereomer: mp 66 - 68 °C; $[\alpha]_D^{20}$ −8.7 (*c* 1, CH_3OH); ^1H NMR (400 MHz, $CDCl_3$) δ 8.06 (d, *J* = 8.4 Hz, 1H), 7.97 (s, 1H), 7.86-7.81 (m, 2H), 7.57-7.47 (m, 4H), 7.06 (s, 1H), 6.67 (q, *J* = 6.8 Hz, 1H), 4.43-4.40 (m, 1H), 3.67 (ddd, *J* = 13.2, 4.0, 1.6 Hz, 1H), 3.17 (dd, *J* = 13.2, 1.6 Hz, 1H), 2.00 (ddd, *J* = 18.8, 2.8, 1.6 Hz, 1H), 1.74-1.67 (m, 1H), 1.69 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.4, 156.6, 134.7, 133.7, 131.2, 129.0, 128.9, 127.2, 126.2, 125.3, 125.2, 123.6, 116.2, 105.0, 100.8, 48.3, 46.6, 44.0, 41.8, 15.2; IR (neat) 2924, 1720, 1644, 1427, 1329, 1128, 781 cm^{-1}; HRMS calcd for [M] $C_{21}H_{18}Br_2N_2O_2$ 487.9735, found 487.9732.

(*S*)-6,7-Dibromo-4-(2-hydroxyethyl)-2-((*R*)-1-(naphthalene-1-yl)ethyl)-3,4-dihydropyrrolo[1,2-*a*]pyrazin-1(2*H*)-one (5). Into a 10 mL flask was placed the tandem product **4b** (170 mg, 0.346 mmol) in ethanol (3.5 mL, 0.1 M). The solution was cooled to 0 °C, and sodium borohydride (16 mg, 0.415 mmol) was added in a single portion. After 30 min, the reaction was quenched by the dropwise addition of 1% HCl solution. The mixture was poured into ethyl acetate. The combined organic layers were washed with saturated $NaHCO_3$ and brine, and dried over Na_2SO_4. Concentration and purification by flash chromatography (SiO_2, 40% EtOAc/hexanes) provided **5** in 94% yield (160 mg) as a white solid: mp 176 - 178 °C; $[\alpha]_D^{20}$ −32.9 (*c* 0.9, CH_3OH); ^1H NMR (400 MHz, $CDCl_3$) δ 8.06 (d, *J* = 8.0 Hz, 1H), 7.84-7.81 (m, 2H), 7.57-7.44 (m, 4H), 7.05 (s, 1H), 6.71 (q, *J* = 6.8 Hz, 1H), 4.32-4.28 (m, 1H), 3.77-3.74 (m, 2H), 3.30 (dd, *J* = 14.0, 1.2 Hz, 1H), 2.81 (dd, *J* = 14.0, 4.4 Hz, 1H), 2.04-1.94 (m, 2H), 1.85-1.77 (m, 1H), 1.73 (d, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.4, 134.4, 133.6, 131.7, 129.1, 128.7, 127.2, 126.1, 125.1, 124.9, 124.8, 123.4, 115.7, 105.4, 100.5, 59.1, 51.3, 46.7, 43.8, 34.8, 17.0; IR (neat) 3425, 2926, 1729, 1627, 1429, 1285, 1129, 1055, 745 cm^{-1}; HRMS calcd for [M] $C_{21}H_{20}Br_2N_2O_2$ 489.9892, found 489.9889.

(*S*)-6,7-Dibromo-4-(2-hydroxyethyl)-3,4-dihydropyrrolo[1,2-*a*]pyrazin-1(2*H*)-one (6). Methanesulfonic acid (159 mg, 1.65 mmol) and anisole (18 μL, 0.165 mmol) were added to a stirred solution of **5** (81 mg, 0.165 mmol) in nitromethane (1.7 mL, 0.1 M), and the mixture was stirred for 4 hours at 120 °C. The reaction mixture was poured into saturated $NaHCO_3$ and extracted twice with dichloromethane. The combined organic layers were dried over $MgSO_4$. Concentration and purification by flash chromatography (SiO_2, 5% MeOH/DCM) provided **6** in 80% yield (45 mg) as a white solid: mp 138 - 139 °C; $[\alpha]_D^{20}$ −31.9 (*c* 1, CH_3OH); ^1H NMR (400 MHz, CD_3OD) δ 6.91 (s, 1H), 4.60-4.56 (m, 1H), 3.80 (ddd, *J* = 13.6, 4.0, 0.4 Hz, 1H), 3.71-3.61 (m, 3H), 1.97-1.95 (m, 1H), 1.87-1.79 (m, 1H); ^{13}C NMR (100 MHz, CD_3OD) δ 161.1, 126.1, 116.4, 108.1, 101.2, 59.3, 53.4, 43.4, 35.5; IR (neat) 3435, 3243, 2922, 1647, 1616, 1544, 1424, 1334, 1053, 959, 749 cm^{-1}; HRMS calcd for [M] $C_9H_{10}Br_2N_2O_2$ 335.9109, found 335.9107.

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References and Notes

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