Asymmetric Synthesis of (1-Ferrocenylalkyl)amine and 1,1′-Bis(1-aminoalkyl)ferrocene Derivatives

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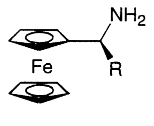
The aldehydes **1** and **5** were converted to the corresponding SAMP hydrazones **2** and **6**, respectively. Subsequent nucleophilic 1,2-addition of organolithium reagents to the C−N double bonds and cleavage of the N−N hydrazine bond using an excess of $BH_3 \cdot THF$ afforded (1-ferrocenylalkyl)amines (*N*-protection → **4**) and 1,1′-bis(1-aminoalkyl)ferrocenes (N-protection → **8**) in good overall yields (32−88%), with very high enantiomeric excesses (*ee* = 90−98%) and *dl*/*meso* ratios of up to 95:5.

Introduction

In the last few years chiral (1-ferrocenylalkyl)amine derivatives have developed into a class of compounds of extraordinary importance. (1-Ferrocenylalkyl)amines **A** have been employed as chiral auxiliaries in the Ugi four-component condensation[1] and in the asymmetric synthesis of the alkaloids (+)- and (−)-corynoline[2]. In addition, there is a steadily increasing interest in these compounds because of their important role as chiral ligands in homogeneous asymmetric catalysis[3].

Due to nucleophilic substitution reactions, which take place under complete retention of the configuration, a broad variety of ligands can be synthesized based on (1-ferrocenylalkyl)amines[4]. These ferrocenylamines have been conveniently prepared through the diastereoselective *ortho*-lithiation of optically active *N*,*N*-dimethyl-(1-ferrocenylethyl)amine (e.g. Kumada ligand **B**), which was obtained by resolution of the racemic amine[5]. There have only been a few reports on convenient methods for the asymmetric synthesis of optically active (1-ferrocenylalkyl)amines. Pyne et al.[6] have published a method for preparing (1-ferrocenylethyl)amine by the diastereoselective hydride reduction of an optically active imine. Several groups have used aminoalcohols as chiral additives in the 1,2-addition of dialkylzinc reagents to ferrocenecarbaldehyde, but this synthesis is limited so far to dimethyl- and diethylzinc[7]. Another disadvantage of this method is the additional steps to convert the resulting (1-ferrocenylalkyl)alcohols into the corresponding amines[8]. Soai et al.[9] synthesized directly (1-ferrocenylalkyl)amines using ferrocenyldiphenylphosphanylimine as starting material in a similar addition reaction. Reeves et al.[10] have reported the enantioselective reduction of acyl ferrocenes using Corey′s chiral oxazaborolidine catalyst.

(1-Ferrocenylalkyl)amine derivatives have been used in asymmetric catalytic hydrogenation, allylic substitution, Grignard cross coupling and aldol reactions[3].



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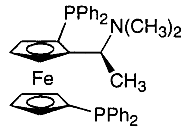

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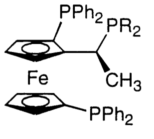

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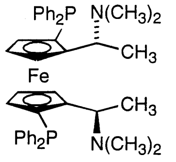

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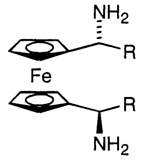

E

The Ciba (*S*)-Metolachlor process and a biotin process at Lonza are two industrial applications of (1-ferrocenylalkyl)amine-based catalysts **C**, which demonstrates the importance of this class of ligands for asymmetric catalysis[11]. The production of the herbicide (*S*)-Metolachlor is the largest process using asymmetric hydrogenation catalysts, generating more than 10,000 tons of (*S*)-Metolachlor per year.

Hayashi et al.[12] reported the first C_2-symmetric tetrasubstituted ferrocene ligand, 2,2′-bis[1-(*N*,*N*-dimethylamino)ethyl]-1,1′-bis(diphenylphosphanyl)ferrocene (**D**), which was prepared by *ortho*-lithiation and phosphanylation of 1,1′-bis[1-(*N*,*N*-dimethylamino)ethyl]ferrocene. However, for the preparation of this ligand a resolution procedure was required. The asymmetric synthesis of 1,1′-bis(1-aminoalkyl)ferrocene-type ligands **E** has been extensively studied during the last few years. Analogously to the (1-ferrocenylalkyl)amines these diamines are derived from their corresponding alcohols. (1*S*,2*R*)-*N*,*N*-dialkylnore-

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phedrines[13] and ferrocenylamino alcohols[14] were used in the asymmetric 1,2-addition of dialkylzinc to ferrocene-1,1′-dicarbaldehyde. Again the scope of the method is limited. 1,1′-Ferrocenyl diketones can also be reduced with Corey's chiral oxazaborolidine catalyst[15]. New approaches have been presented by Togni et al.[16] and Knochel et al.[17], who synthesized 1,1′-bis(1-aminoalkyl)ferrocene derivatives from chiral fulvenes. 1,1′-Bis(1-aminoalkyl)ferrocene derivatives have been used as chiral catalyst in the reduction of acetophenone and 1-acetylnaphthalene[18].

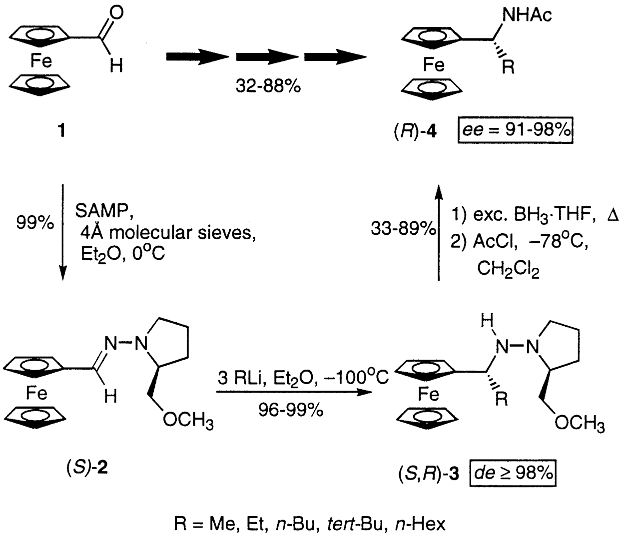
We now like to report in detail our work on the asymmetric synthesis of (1-ferrocenylalkyl)amines and 1,1′-bis(1-aminoalkyl)ferrocenes, in which the nucleophilic 1,2-addition of organolithium compounds to a SAMP or RAMP hydrazone is the key reaction step[19].

Results and Discussion

(1-Ferrocenylalkyl)amine Derivatives

The commercially available ferrocenecarbaldehyde (**1**) was converted to the corresponding SAMP hydrazone (*S*)-**2** in almost quantitative yield (Scheme 1). Nucleophilic 1,2-addition of organolithium compounds to the hydrazone C−N double bond was subsequently carried out at −100°C in diethyl ether. The use of three equivalents of the alkyllithium reagent was necessary to obtain very good yields (96−99%). The addition reactions occurred with virtually complete asymmetric induction. The 1,2-addition of phenyllithium gave the corresponding hydrazine **3f** in 96% yield and with 84% *ee*. After work up, the air-sensitive hydrazines **3a−f** were obtained as yellow brown oils and were immediatly employed in the N−N bond cleavage without further purification.

Scheme 1. Asymmetric synthesis of protected (1-ferrocenylalkyl)amines



Common N−N bond-cleavage methods include lithium in liquid ammonia[20] and samarium diiodide[21]. To use these cleavage reagents, the non-activated hydrazines **3** were in situ protected with acetyl chloride. This protecting reaction gave only moderate yields (34%) and the cleavage reactions gave ethylferrocene (33%, using Li/NH$_3$) and vinylferrocene (90%, using SmI$_2$), respectively, as main products. The N−N bond cleavage of the non-activated hydrazines **3a−f** was accomplished by hydrogenolysis in the presence of a catalyst. Platinum dioxide[22] gave in the case of (1-ferrocenylethyl)amine low yields (29%) and significant loss of optical purity (*ee* = 75%). With other hydrazines, e.g. **3e**, side products, like (1-ferrocenylheptyl) methyl ether, became main products. The Raney nickel[23] promoted hydrogenolysis of the hydrazines **3a−e** afforded the (1-ferrocenylalkyl)amines in overall yields of 30−54% and enantiomeric excesses of 85−94%. This N−N bond-cleavage protocol suffers from a number of disadvantages. The reaction conditions are rather harsh (10 bar H$_2$, 60°C), the preparation of the Raney nickel catalyst is very tedious, hydrogenation of aromatic residues can become competitive and the partial epimerization or racemization during the cleavage reaction could not be avoided even by variation of the hydrogenolysis conditions. In order to cleave the N−N bond of the hydrazines **3a−e** we explored a new reductive cleavage method using BH$_3$·THF as novel reducing reagent. When hydrazines **3a−e** were treated with a large excess of borane (10 equivalents) in refluxing THF the (1-ferrocenylalkyl)amines could be isolated as their acetamide derivatives **4a−e** in good yields (up to 89%) and very good enantiomeric excesses (*ee* = 91−98%). The moderate yield of the *tert*-butyl derivative **4d** is probably due to steric hinderance. (1-Ferrocenyl-1-phenylmethyl)amide **4f** could be isolated in 71% yield and with an enantiomeric excess of 76%. The advantages of this new protocol are the compatibility with aryl derivatives in the starting hydrazine and the easy and fast general procedure giving better yields and inductions than common N−N cleavage methods.

The enantiomeric excesses of the (1-ferrocenylalkyl)amides **4a−e** and (1-ferrocenyl-1-phenylmethyl)amide **4f** were determined by HPLC analysis employing chiral stationary phases. The racemic compounds *rac*-**4a−f** required for comparison were synthesized from the corresponding achiral *N*,*N*-dimethylhydrazones. Of course, both enantiomers of the amides **4a−f** can be obtained as desired by use of SAMP or RAMP as chiral auxiliaries, which is shown for product (*R*)- and (*S*)-**4c**.

The absolute configurations were determined by X-ray structure analysis of the hydrazine (*S*,*R*)-**3d** (Figure 1)[24] and by NOE-NMR experiments. Suitable orange crystals were obtained by recrystallization from petroleum ether. From the structure analysis, the absolute configuration of the stereogenic center generated by the 1,2-addition is established as (*R*) when SAMP was used as auxiliary, which is in agreement with the diastereofacial selectivities previously observed for 1,2-additions of organometallic compounds to the C−N double bond of aldehyde SAMP hydrazones[23].

1,1′-Bis(1-aminoalkyl)ferrocene Derivatives

Analogous to the presented synthesis of (1-ferrocenylalkyl)amines, an aldehyde is the starting material for the synthesis of 1,1′-bis(1-aminoalkyl)ferrocene derivatives. Ferrocene-1,1′-dicarbaldehyde (**5**) could be synthesized in good

Table 1. Enantioselective synthesis of (*R*)-*N*-(1-ferrocenylalkyl)amides (*R*)-**4a−e** by 1,2-addition of organolithium compounds to ferrocenecarbaldehyde SAMP hydrazone [(*S*)-**2**], followed by reductive cleavage of the N−N bond of hydrazines (*S*,*R*)-**3a−e**

3, 4	R	yield **2** → **3** [%]	*de*(**3**)[a]	$[\alpha]_D^{22}$ (c = 1, $CHCl_3$)	$BH_3 \cdot THF$ [equiv.]	*T* [°C]	yield **3** → **4** [%]	*ee*[b] [%]	$[\alpha]_D^{22}$ (c = 1, C_6H_6)	config.
a	Me	99	≥98	−126.6	10	RT	89	95	−83.7	*R*
b	Et	96	≥98	−164.5	10	60	72	98	−25.8[c]	*R*
c	*n*Bu	98	≥98	−165.7	20	60	82	95	−44.8	*R*
c	*n*Bu	98	≥98	–	10	60	64	94	+42.5	*S*[d]
d	*t*Bu	96	≥98	−222.4	10	60	33	91	+89.7	*R*
e	*n*Hex	99	≥98	−149.5	20	60	80	93	−21.5	*R*
f	Ph	96	≥84	–	10	60	71	76	−35.1[e]	*R*

[a] Determined by ^{1}H- and ^{13}C-NMR spectroscopy. – [b] Enantiomeric excesses were determined on the acetyl derivatives of the amines by HPLC (Chiralcel® OD). – [c] (c = 0.5, $CHCl_3$). – [d] Ferrocenecarbaldehyde RAMP hydrazone [(*R*)-**2**] was used as starting material. – [e] (c = 0.25, $CHCl_3$).

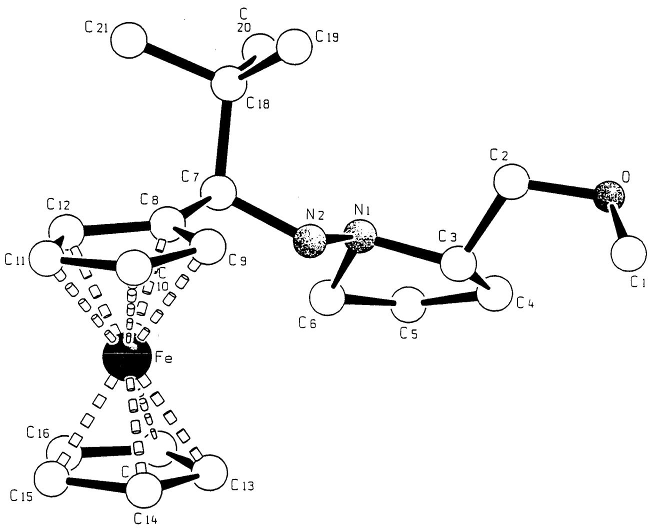
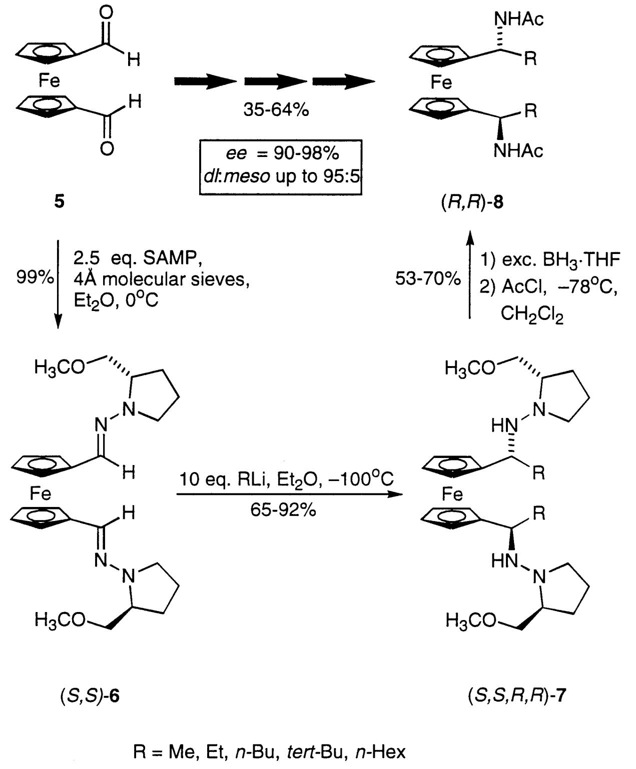


Figure 1. X-ray structure of the hydrazine (*S*,*R*)-**3d** in the solid state (ORTEP plot)

Scheme 2. Asymmetric synthesis of protected 1,1′-bis(1-aminoalkyl)ferrocenes



yield from inexpensive ferrocene using the dilithiation method according to Widdowson et al.[25]. The ferrocene-1,1′-dicarbaldehyde (**5**) was treated with 2.5 equivalents of the auxiliary SAMP in diethyl ether at 0 °C in the presence of molecular sieves (Scheme 2) to give the bishydrazone (*S*,*S*)-**6** in almost quantitative yield.

For achieving high yields in the subsequent double 1,2-addition of organolithium compounds to the C−N double bonds of the bishydrazone (*S*,*S*)-**6**, a large excess (10 equivalents) of the lithium reagent was required (Table 2). The large excess of the alkyllithium compounds did not appear to have any effect on the stereoselectivities. The best results were obtained by the use of small alkyllithium compounds (R = Me, Et) at −100 °C in diethyl ether, whereas the bulky *tert*-butyl derivative **7d** was isolated in only moderate yield, probably due to steric hindrance. In comparison with the synthesis of the racemic 1,1′-bis(1-aminoalkyl)ferrocenes from their corresponding bis(*N*,*N*-dimethylhydrazones), where 6.3 equivalents of the organolithium compound were used, a larger amount of the lithium reagent in the asymmetric case could be explained by additional complexation opportunities due to the methoxy groups.

The N−N bond cleavage of the bishydrazines **7a−e** was first accomplished by hydrogenolysis in the presence of several modified Raney nickel catalysts. After reductive cleavage of the N−N bonds, the desired air-sensitive primary diamines were directly converted into their corresponding bisacetamide derivatives (*R*,*R*)-**8a−e**. Good yields (71%) and stereoselectivities (*ee* = 96%, *dl*/*meso* = 91:9) could only be obtained in the case of bishydrazine **7a**. For comparison, Raney nickel promoted hydrogenolysis of the *tert*-butyl derivative **7d** afforded the diamide **8d** in only moderate yield (31%), an enantiomeric excess of 91% and a disappointing *dl*/*meso* ratio of 51:49. To avoid the partial epimerization and to simplify the reaction sequence, our new $BH_3 \cdot THF$ cleavage method was applied to the bishydrazines. As shown in Table 2, the use of a large excess (20

Table 2. Diastereo- and enantioselective synthesis of 1,1′-bis(1-acetaminoalkyl)ferrocenes **8a−e** by 1,2-addition of alkyllithium compounds to ferrocene-1,1′-dicarbaldehyde bis(SAMP hydrazone) [(*S*,*S*)-**6**], followed by reductive N−N bond cleavage of bishydrazines **7a−e**

7, 8	R	yield **6** → **7** [%]	$[\alpha]_D^{22}$(**7**)[a] (*c*, $CHCl_3$)	yield **7** → **8** [%]	*ee*(**8**)[b] [%]	*dl*/*meso* **8**[b]	$[\alpha]_D^{22}$(**8**) (*c*, $CHCl_3$)	config.
a	Me	82	−194 (0.26)	69	96	92:8	−30.8 (0.25)	*R*,*R*[c]
b	Et	92	−152 (0.25)	70	94	90:10	−22.7 (0.26)	*R*,*R*[c]
c	*n*Bu	72	−94 (0.10)	69	98	95:5	−24.0 (0.25)	*R*,*R*[c]
d	*t*Bu	65	+212 (0.25)	58	93	80:20	−35.4 (1.30)	*S*,*S*[c]
e	*n*Hex	71	−101 (0.25)	53	90	90:10	−20.0 (0.35)	*R*,*R*[c]

[a] Optical rotations were determined on the crude bishydrazines **7a−e**. − [b] Enantiomeric excesses and *dl*/*meso* ratios were determined on MTPA amides of the amines by ^{1}H-, ^{13}C-, and ^{19}F-NMR spectroscopy. − [c] Ferrocene-1,1′-dicarbaldehyde bis(RAMP hydrazone) [(*R*,*R*)-**6**] was used as starting material.

equivalents) of the cleavage reagent was necessary to obtained good yields of the protected 1,1′-bis(1-aminoalkyl)-ferrocenes (53−70%). The stereoselectivities are in the range of *ee* = 90−98% and *dl*/*meso* ratios up to 95:5[26]. The *ee* and *dl*/*meso* values of the diamine derivatives **8a−e** were determined by ^{1}H-, ^{13}C-, and ^{19}F-NMR spectroscopy performed on the corresponding Mosher amides (MTPA amides)[27]. The absolute configurations were determined by NOE-NMR experiments on the bishydrazines and are in agreement with the observed results for the monohydrazines.

Conclusion

In summary, an efficient C−C connective asymmetric synthesis of protected (1-ferrocenylalkyl)amines and 1,1′-bis(1-aminoalkyl)ferrocenes starting from readily available substrates has been developed. In order to cleave the N−N bonds of SAMP hydrazines we have worked out a novel reductive cleavage method. The ferrocene derivatives obtained could find application as novel ligands in asymmetric catalysis.

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Experimental Section

All solvents were dried and distilled before use. − Column chromatography: Merck silica gel 60, 0.040−0.063 mm (230−400 mesh) (flash). − Optical rotation values: Perkin-Elmer P 241, solvent UVASOL-quality. − Melting points (uncorrected): Büchi 510. − IR: Perkin-Elmer FT 1750. − NMR: Varian VXR 300 and Gemini 300 (300 and 75 MHz for ^{1}H and ^{13}C, respectively), Varian Unity 500 (500 and 125 MHz for ^{1}H and ^{13}C, respectively), $CDCl_3$ or C_6D_6 as solvent, TMS as internal standard. − MS: Finnigan MAT (70 eV) and Finnigan SSQ 7000 (70 eV). − Elemental analyses (C,H,N): Elementar vario EL. − High-resolution MS: Finnigan MAT, MAT 95. − The diastereomeric and enantiomeric excess of a reaction was determined by HPLC analysis employing chiral stationary phases or NMR spectroscopy.

1. *General Procedure for the Preparation of the SAMP Hydrazones* (GP 1): A mixture of aldehyde, molecular sieves (4 Å), and 1.0 or 2.5 equivalents of SAMP/RAMP in dry diethyl ether or diethyl ether/dichloromethane (4:1) was stirred overnight and then diluted with diethyl ether, dried with $MgSO_4$ and concentrated in vacuo. The crude products were purified by flash column chromatography.

2. *General Procedure for the Nucleophilic 1,2-Addition to the Hydrazone C−N Double Bonds* (GP 2): The hydrazones were dissolved in dry ether (12 ml/mmol) and cooled to −100°C. At this temperature 3 or 10 equivalents, respectively, of organolithium reagent (1.6 M in pentane, ether, or *n*-hexane) were added dropwise into the solution (20 ml/h) under argon. Upon warming to room temperature overnight, the solution was quenched at 0°C with water (2 ml/mmol). The reaction mixture was then washed with saturated aqueous NaCl (3 × 20 ml/mmol) and dried with $MgSO_4$ and concentrated in vacuo. The air-sensitive (bis)hydrazines were used without further purification.

3. *General Procedure for the Hydrazine N−N Bond Cleavage* (GP 3): The hydrazines were dissolved in dry THF (20 ml/mmol). After adding 10 or 20 equivalents of $BH_3 \cdot THF$ (1.0 M in THF), respectively, the mixture was heated under reflux for 5 h. The reaction was cooled to −5°C and quenched with 4 N hydrochloric acid and stirred for 1.5 h. The THF was evaporated under reduced presure and the aqueous solution was basified with solid sodium hydroxide. After stirring for 0.5 h, the amines or diamines were extracted with Et_2O/CH_2Cl_2 (3:1, 3 × 40 ml/mmol) and concentrated to dryness. The air-sensitive yellow-orange amines and diamines were converted into their corresponding acetamides. Therefore, the crude products were treated at −78°C under argon with 10−20 equivalents of Et_3N and 1.25−4 equivalents of AcCl in dry CH_2Cl_2. After warming to room temperature overnight, the reaction mixture was washed with saturated aqueous NH_4Cl (3 × 20 ml/mmol), saturated aqueous NaCl (3 × 20 ml/mmol) and dried with $MgSO_4$. The crude products were purified by flash column chromatography (SiO_2, pentane or petroleum ether/ethyl acetate, 1:1).

Ferrocenecarbaldehyde SAMP Hydrazone [(*S*)-**2**][28]: A mixture of ferrocenecarbaldehyde (15 g, 70 mmol), 15 g of molecular sieves (4 Å), and SAMP (10 g, 77 mmol) in dry diethyl ether (70 ml) was stirred at 0°C overnight and then diluted with diethyl ether (130 ml), dried with $MgSO_4$, and concentrated in vacuo. The crude product was purified by flash column chromatography (SiO_2, ether/petroleum ether, 2:1), to yield 22.6 g of (*S*)-**2** (99%) as orange crystals. − M.p. = 59°C. − $[\alpha]_D^{22}$ = +14.5 (*c* = 1.0, $CHCl_3$). − IR (KBr): $\tilde{\nu}$ = 1581 cm^{-1} (s, C=N). − ^{1}H NMR (300 MHz, C_6D_6): δ = 1.47−1.83 (m, 4 H, CH_2CH_2), 2.70 (m, 1 H, NC*H*H), 3.14 (m, 1 H, NCH*H*), 3.16 (s, 3 H, OCH_3), 3.46 (m, 1 H, CH_2O), 3.64−3.74 (m, 2 H, CH_2O, NC*H*CH_2), 4.07 (s, 5 H, C_5H_5), 4.11 (m, 2 H, C_5H_4), 4.62 (m, 2 H, C_5H_4), 7.01 (s, 1 H, NC*H*). − ^{13}C NMR (75 MHz, C_6D_6): δ = 22.51 (CH_2), 27.39 (CH_2), 49.54 (NCH_2), 59.04 (OCH_3) 63.63 (*C*H), 66.72 (C_5H_4), 66.75 (C_5H_4), 68.91 (C_5H_4), 69.49 (C_5H_5), 75.57 (CH_2O), 84.70 (*ipso*-C_5H_4), 131.82 (*C*=N). −

MS (70 eV); *m*/*z* (%): 326.1 (72) [M$^+$], 212.1 (100) [M$^+$ − C$_6$H$_{12}$NO], 184.9 (82) [Fc$^+$]. − C$_{17}$H$_{22}$FeN$_2$O (326.2): calcd. C 62.59, H 6.80, N 8.59; found C 62.54, H 6.92, N 8.43.

(1R,2′S)-(1-Ferrocenylethyl)[2′-(methoxymethyl)-1′-pyrrolidinyl]amine [(1*R*,2′*S*)-**3a**]: 17.7 ml of a 1.6 M methyllithium solution in diethyl ether and 3.08 g (9.44 mmol) of ferrocenecarbaldehyde SAMP hydrazone [(*S*)-**2**] were allowed to react in 60 ml of dry diethyl ether according to GP2, yielding 3.19 g of (1*R*,2′*S*)-**3a** (99%) as a yellow-brown oil. − $[\alpha]_D^{22} = -126.6$ (*c* = 1.03, CHCl$_3$). − IR (KBr): $\tilde{\nu}$ = 3097 cm^{-1} (w, NH). − ^{1}H NMR (500 MHz, C$_6$D$_6$): δ = 1.47 (d, *J* = 6 Hz, 3 H, CH_3), 1.52 (m, 1 H, NCH$_2$CHH), 1.62 (m, 1 H, NCH$_2$CHH), 1.71 (m, 1 H, CHCHH), 1.89 (m, 1 H, NCHH), 1.94 (m, 1 H, CHCHH), 2.44 (br. s, 1 H, NH), 2.74 (d/q, *J* = 4/8 Hz, 1 H, NCH ring), 3.23 (s, 3 H, OCH_3), 3.35 (m, 1 H, NCHH), 3.40 (d/d, *J* = 8/9 Hz, 1 H, OCHH), 3.72 (q, *J* = 6 Hz, 1 H, CHCH$_3$), 3.87 (d/d, *J* = 4/9 Hz, 1 H, OCHH), 3.97 (m, 1 H, β-C$_5$$H_4$), 3.99 (m, 1 H, β-C$_5$$H_4$), 4.05 (s, 5 H, C$_5$$H_5$), 4.07 (m, 1 H, α-C$_5$$H_4$), 4.22 (m, 1 H, α-C$_5$$H_4$). − ^{13}C NMR (125 MHz, C$_6$D$_6$): δ = 21.45 (CH$_2$), 22.35 (CH$_3$), 27.31 (CH$_2$), 53.07 (CHCH$_3$) 56.93 (NCH$_2$), 58.91 (OCH$_3$), 65.78 (NCH), 66.76 (C_5H$_4$), 66.83 (C_5H$_4$), 67.65 (C_5H$_4$), 67.68 (C_5H$_4$), 68.77 (C_5H$_5$), 76.24 (CH$_2$O), 93.06 (*ipso*-C_5H$_4$). − MS (70 eV); *m*/*z* (%): 342.0 (8) [M$^+$], 212.9 (100) [M$^+$ − C$_6$H$_{13}$N$_2$O]. − C$_{18}$H$_{26}$FeN$_2$O (342.2): calcd. C 63.17, H 7.66, N 8.19; found C 63.21, H 7.49, N 8.03.

(1R,2′S)-(1-Ferrocenylpropyl)[2′-(methoxymethyl)-1′-pyrrolidinyl]amine [(1*R*,2′*S*)-**3b**]: Ethyllithium (2.08 g EtI, 17.6 ml of 1.6 M *t*BuLi)[8] and 1.30 g (4 mmol) of ferrocenecarbaldehyde SAMP hydrazone [(*S*)-**2**] were allowed to react in 24 ml of dry diethyl ether according to GP2, yielding 1.37 g of (1*R*,2′*S*)-**3b** (96%) as a yellow-brown oil. − $[\alpha]_D^{22} = -164.5$ (*c* = 1.0, CHCl$_3$). − IR (KBr): $\tilde{\nu}$ = 3095 cm^{-1} (w, NH). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 0.92 (t, *J* = 7 Hz, 3 H, CH_3), 1.49−2.12 (m, 7 H, CH_2, CH_2CH$_3$, NCHH), 2.80 (d/q, *J* = 4/8 Hz, 1 H, NCH), 2.85 (br. s, 1 H, NH), 3.25 (s, 3 H, OCH_3), 3.44 (m, 2 H, NCHH, NCH), 3.50 (m, 1 H, OCHH), 3.92 (m, 1 H, OCHH), 3.96 (m, 1 H, C$_5$$H_4$), 3.98 (m, 1 H, C$_5$$H_4$), 4.00 (m, 4 H, C$_5$$H_4$), 4.05 (s, 5 H, C$_5$$H_5$), 4.27 (m, 1 H, C$_5$$H_4$). − ^{13}C NMR (75 MHz, C$_6$D$_6$): δ = 10.10 (CH$_3$), 21.40 (NCH$_2$$CH_2$), 27.29 (NCH$CH_2$), 28.92 ($CH_2CH_3$) 56.81 (N$CH_2$), 58.65 ($C$H), 58.89 (O$CH_3$), 66.02 (N$C$H), 66.15 ($C_5H_4$), 67.29 ($C_5H_4$), 67.58 ($C_5H_4$), 67.98 ($C_5H_4$), 68.68 ($C_5H_5$), 76.12 ($CH_2$O), 91.88 (*ipso*-$C_5H_4$). − MS (70 eV); *m*/*z* (%): 356.0 (8) [M$^+$], 227.0 (100) [M$^+$ − C$_6$H$_{13}$N$_2$O]. − C$_{19}$H$_{28}$FeN$_2$O (356.3): calcd. C 64.05, H 7.92, N 7.86; found C 64.07, H 7.68, N 7.95.

(1R,2′S)-(1-Ferrocenylpentyl)[2′-(methoxymethyl)-1′-pyrrolidinyl]amine [(1*R*,2′*S*)-**3c**]: 17.3 ml of a 1.6 M *n*-BuLi solution in *n*-hexane and 3.00 g (9.20 mmol) of ferrocenecarbaldehyde SAMP hydrazone [(*S*)-**2**] were allowed to react in 75 ml of dry diethyl ether according to GP2, yielding 3.46 g of (1*R*,2′*S*)-**3c** (98%) as a yellow-brown oil. − $[\alpha]_D^{22} = -165.7$ (*c* = 1.05, CHCl$_3$). − IR (KBr): $\tilde{\nu}$ = 3094 cm^{-1} (w, NH). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 0.89 (t, *J* = 7 Hz, 3 H, CH_3), 1.24−2.12 [m, 11 H, CH_2, (CH_2)$_3$, NCHH], 2.81 (d/q, *J* = 3/8 Hz, 1 H, NCH), 2.88 (br. s, 1 H, NH), 3.26 (s, 3 H, OCH_3), 3.43 (m, 1 H, NCHH), 3.47 (t, *J* = 8 Hz, 1 H, CH*n*Bu), 3.58 (d/d, *J* = 4/7 Hz, 1 H, OCHH), 3.92 (d/d, *J* = 4/9 Hz, 1 H, OCHH), 3.98 (m, 2 H, C$_5$$H_4$), 4.04 (m, 1 H, C$_5$$H_4$), 4.07 (s, 5 H, C$_5$$H_5$), 4.29 (m, 1 H, C$_5$$H_4$). − ^{13}C NMR (75 MHz, C$_6$D$_6$): δ = 14.59 (CH$_3$), 21.56 (NCH$_2$$CH_2$), 23.56 ($CH_2$), 27.34 (NCH$CH_2$), 28.26 ($CH_2$), 36.22 ($CH_2$), 57.02 (N$CH_2$), 57.59 ($C$H), 59.01 (O$CH_3$), 66.23 ($C_5H_4$), 66.36 ($C_5H_4$), 67.41 (N$C$H), 67.76 ($C_5H_4$), 68.05 ($C_5H_4$), 68.84 ($C_5H_5$), 76.18 ($CH_2$O), 92.60 (*ipso*-$C_5H_4$). − MS (70 eV); *m*/*z* (%): 384.0 (15) [M$^+$], 254.9 (100) [M$^+$ − C$_6$H$_{13}$N$_2$O]. − C$_{21}$H$_{32}$FeN$_2$O (384.4): calcd. C 65.63, H 8.39, N 7.29; found C 65.29, H 8.41, N 7.54.

(1R,2′S)-(1-Ferrocenyl-2,2-dimethylpropyl)[2′-(methoxymethyl)-1′-pyrrolidinyl]amine [(1*R*,2′*S*)-**3d**]: 8.1 ml of a 1.6 M *t*BuLi solution in pentane and 1.40 g (4.3 mmol) of ferrocenecarbaldehyde SAMP hydrazone [(*S*)-**2**] were allowed to react in 10 ml of dry diethyl ether according to GP2, yielding 1.58 g of (1*R*,2′*S*)-**3d** (96%) as a yellow-brown oil. − $[\alpha]_D^{22} = -222.4$ (*c* = 1.0, CHCl$_3$). − IR (KBr): $\tilde{\nu}$ = 3086 cm^{-1} (m, NH). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 1.08 [s, 9 H, C(CH_3)$_3$], 1.49−2.01 [m, 6 H, (CH_2)$_2$, NCHH, NH], 2.68 (d/q, *J* = 3/8 Hz, 1 H, NCH), 3.25 (s, 3 H, OCH_3), 3.30 [s, 1 H, CH(CH$_3$)$_3$], 3.48−3.60 (m, 2 H, NCHH, OCHH), 3.91−3.95 (m, 2 H, OCHH, C$_5$$H_4$), 3.98 (m, 1 H, C$_5$$H_4$), 4.05 (s, 5 H, C$_5$$H_5$), 4.16 (m, 2 H, C$_5$$H_4$). − ^{13}C NMR (75 MHz, C$_6$D$_6$): δ = 21.12 (NCH$_2$$CH_2$), 27.18 (NCH$CH_2$), 28.37 [C($CH_3$)$_3$], 35.50 [$C$(CH$_3$)$_3$], 55.80 (N$CH_2$), 58.84 (O$CH_3$), 64.03 ($C$H), 66.25 ($C_5H_4$), 66.87 ($C_5H_4$), 66.95 ($C_5H_4$), 67.37 ($C_5H_4$), 68.95 ($C_5H_5$), 70.12 (N$C$H), 75.72 ($CH_2$O), 91.82 (*ipso*-$C_5H_4$). − MS (70 eV); *m*/*z* (%): 384.1 (9) [M$^+$], 327.0 (19) [M$^+$ − C(CH$_3$)$_3$], 185.9 (100) [Fe(C$_5$H$_5$)$_2$]. − C$_{21}$H$_{32}$FeN$_2$O (384.4): calcd. C 65.63, H 8.39, N 7.29; found C 65.94, H 8.43, N 7.23.

(1R,2′S)-(1-Ferrocenylheptyl)[2′-(methoxymethyl)-1′-pyrrolidinyl]amine [(1*R*,2′*S*)-**3e**]: 6.0 ml of a 2.0 M *n*HexLi solution in *n*-hexane and 1.31 g (4.0 mmol) of ferrocenecarbaldehyde SAMP hydrazone [(*S*)-**2**] were allowed to react in 35 ml of dry diethyl ether according to GP2, yielding 1.64 g of (1*R*,2′*S*)-**3e** (99%) as a yellow-brown oil. − $[\alpha]_D^{22} = -149.5$ (*c* = 1.05, CHCl$_3$). − IR (KBr): $\tilde{\nu}$ = 3094 cm^{-1} (m, NH). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 0.85 (t, *J* = 7 Hz, 3 H, CH$_3$), 1.20−2.12 [m, 15 H, (CH_2)$_5$, (CH_2)$_2$, NCHH], 2.80 (d/d/d, *J* = 3/3/8 Hz, 1 H, NCH), 2.81 (br. s, 1 H, NH), 3.27 (s, 3 H, OCH_3), 3.47 (m, 2 H, NCHH, NCH), 3.59 (d/d, *J* = 4/7, 1 H, OCHH), 3.93 (d/d, *J* = 3/9, 1 H, OCHH), 3.97 (m, 1 H, C$_5$$H_4$), 4.00 (m, 1 H, C$_5$$H_4$), 4.05 (m, 1 H, C$_5$$H_4$), 4.07 (s, 5 H, C$_5$$H_5$), 4.30 (m, 1 H, C$_5$$H_4$). − ^{13}C NMR (75 MHz, C$_6$D$_6$): δ = 14.33 (CH$_3$), 21.44 (NCH$_2$$CH_2$), 23.08 ($CH_2$), 25.96 ($CH_2$), 27.26 (NCH$CH_2$), 30.13 ($CH_2$), 32.42 ($CH_2$), 36.44 ($CH_2$), 56.92 (N$CH_2$), 57.51 ($C$H), 58.91 (O$CH_3$), 66.13 (N$C$H), 66.24 ($C_5H_4$), 67.31 ($C_5H_4$), 67.63 ($C_5H_4$), 67.93 ($C_5H_4$), 68.73 ($C_5H_5$), 76.12 ($CH_2$O), 92.50 (*ipso*-$C_5H_4$). − MS (70 eV); *m*/*z* (%): 412.1 (12) [M$^+$], 283.0 (100) [MH$^+$ − SAMP]. − C$_{23}$H$_{36}$FeN$_2$O (412.4): calcd. C 66.99, H 8.80, N 6.79; found C 67.04, H 8.79, N 7.02.

(1S,2′R)-(1-Ferrocenyl-1-phenylmethyl)[2′-(methoxymethyl)-1′-pyrrolidinyl]amine [(1*S*,2′*R*)-**3f**]: 5.0 ml of a 1.8 M phenyllithium solution in cyclohexane/diethyl ether (70:30) and 0.98 g (3.0 mmol) of ferrocenecarbaldehyde SAMP hydrazone [(*S*)-**2**] were allowed to react in 30 ml of dry diethyl ether according to GP2, yielding 1.17 g of (1*R*,2′*S*)-**3f** (96%) as brown crystals. − IR (KBr): $\tilde{\nu}$ = 3086 cm^{-1} (m, NH). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 1.30−2.08 [m, 6 H, (CH_2)$_2$, NCHH, NH], 2.78 (d/q, *J* = 4/7 Hz, 1 H, NCH), 2.95 (d/d, *J* = 8/9 Hz, OCHH), 3.03 (s, 3 H, OCH_3), 3.48 (m, 1 H, NCHH), 3.61 (d/d, *J* = 4/9 Hz, 1 H, OCHH), 3.92 (m. 1 H, C$_5$$H_4$), 3.96 (m, 2 H, C$_5$$H_4$), 4.03 (s, 5 H, C$_5$$H_5$), 4.32 (m, 1 H, C$_5$$H_4$), 4.74 (s, 1 H, aromatic H), 7.06−7.56 (m, 5 H, aromatic H). − ^{13}C NMR (75 MHz, C$_6$D$_6$): δ = 21.41 (NCH$_2$$CH_2$), 27.33 (NCH$CH_2$), 56.65 (N$CH_2$), 58.74 (O$CH_3$), 62.99 ($C$H), 65.75 (N$C$H), 66.64 ($C_5H_4$), 67.68 ($C_5H_4$), 67.70 ($C_5H_4$), 68.05 ($C_5H_4$), 68.97 ($C_5H_5$), 75.97 ($CH_2$O), 92.13 (*ipso*-$C_5H_4$), 127.00 ($C_6H_5$), 127.92 ($C_6H_5$), 128.62 ($C_6H_5$), 145.30 (*ipso*-$C_6H_5$). − MS (70 eV); *m*/*z* (%): 403.9 (6) [M$^+$], 274.9 (100) [M$^+$ − C$_6$H$_{13}$N$_2$O]. − HRMS C$_{23}$H$_{26}$^{56}FeN$_2$O: calcd. 402.1394; found 402.1398.

(1R)-N-(1-Ferrocenylethyl)acetamide [(1*R*)-**4a**]: 154 mg (0.45 mmol) of hydrazine (1*R*,2′*S*)-**3a** was cleaved according to GP3. The resulting (1-ferrocenylethyl)amine was in situ protected with 0.042 ml of AcCl in the presence of Et$_3$N (2.5 equiv.) yielding 109 mg of

(1*R*)-**4a** (89%) as yellow crystals. − [α]$_D^{22}$ = −83.7 (*c* = 1.0, C$_6$H$_6$). − IR (KBr): ṽ = 1650 cm^{-1} (s, CO). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 1.30 (d, *J* = 7 Hz, 3 H, C*H*$_3$), 1.58 (s, 3 H, CH$_3$), 3.93 (m, 3 H, C$_5$*H*$_4$), 3.98 (s, 5 H, C$_5$*H*$_5$), 4.11 (m, 1 H, C$_5$*H*$_4$), 5.12 (q, *J* = 7 Hz, 1 H, NC*H*), 5.16 (br. s, 1 H, N*H*). − ^{13}C NMR (75 MHz, C$_6$D$_6$): δ = 20.97 (*C*H$_3$), 23.07 (CO*C*H$_3$), 43.92 (*C*H), 66.01 (*C*$_5$H$_4$), 67.64 (*C*$_5$H$_4$), 67.83 (*C*$_5$H$_4$), 68.19 (*C*$_5$H$_4$), 68.93 (*C*$_5$H$_5$), 91.96 (*ipso-C*$_5$H$_4$), 167.67 (*C*O). − MS (70 eV); *m/z* (%): 271.0 (100) [M$^+$], 206.0 (58) [M$^+$ − C$_5$H$_5$]. − C$_{14}$H$_{17}$FeNO (271.14): calcd. C 62.03, H 6.32, N 5.17; found C 61.50, H 6.50, N 5.24.

(1R)-N-(1-Ferrocenylpropyl)acetamide [(1*R*)-**4b**]: 214 mg (0.60 mmol) of hydrazine (1*R*,2′*S*)-**3b** was cleaved according to GP3. The resulting (1-ferrocenylpropyl)amine was in situ protected with 0.058 ml of AcCl in the presence of Et$_3$N (2.5 equiv.) yielding 123 mg of (1*R*)-**4b** (72%) as yellow crystals. − [α]$_D^{22}$ = −25.8 (*c* = 0.5, CHCl$_3$). − IR (KBr): ṽ = 1645 cm^{-1} (s, CO). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 0.92 (t, *J* = 7 Hz, 3 H, C*H*$_3$), 1.45 (d/d/q, *J* = 2/5/7 Hz, 1 H, CH*H*), 1.71 (s, 3 H, CH$_3$), 1.75 (d/d/q, *J* = 2/5/7 Hz, 1 H, C*H*H), 3.96 (m, 3 H, C$_5$*H*$_4$), 4.06 (s, 5 H, C$_5$*H*$_5$), 4.11 (m, 1 H, C$_5$*H*$_4$), 5.01 (m, 1 H, NC*H*), 5.46 (br. d, *J* = 9 Hz, 1 H, N*H*). − ^{13}C NMR (75 MHz, C$_6$D$_6$): δ = 11.06 (*C*H$_3$), 23.11 (CO*C*H$_3$), 29.68 (*C*H$_2$), 49.48 (*C*H), 66.73 (*C*$_5$H$_4$), 66.90 (*C*$_5$H$_4$), 67.59 (*C*$_5$H$_4$), 67.87 (*C*$_5$H$_4$), 69.63 (*C*$_5$H$_5$), 91.91 (*ipso-C*$_5$H$_4$), 168.30 (*C*O). − MS (70 eV); *m/z* (%): 285.1 (100) [M$^+$], 220.1 (43) [M$^+$ − C$_5$H$_5$]. − C$_{15}$H$_{19}$FeNO (285.17): calcd. C 63.18, H 6.72, N 4.91; found C 63.05, H 6.79, N 4.90.

(1R)-N-(1-Ferrocenylpentyl)acetamide [(1*R*)-**4c**]: 160 mg (0.42 mmol) of hydrazine (1*R*,2′*S*)-**3c** was cleaved according to GP3. The resulting (1-ferrocenylpentyl)amine was in situ protected with 0.072 ml of AcCl in the presence of Et$_3$N (2.5 equiv.) yielding 107 mg of (1*R*)-**4c** (82%) as yellow crystals. − [α]$_D^{22}$ = −44.8 (*c* = 1.0, C$_6$H$_6$). − IR (KBr): ṽ = 1641 cm^{-1} (s, CO). − ^{1}H NMR (300 MHz, CDCl$_3$): δ = 0.91 (t, *J* = 7 Hz, 3 H, C*H*$_3$), 1.25−1.47 [m, 1 H, (C*H*$_2$)$_2$], 1.58 (m, 1 H, CHCH*H*), 1.79 (m, 1 H, CHC*H*H), 1.84 (s, 3 H, CH$_3$), 3.98 (m, 1 H, C$_5$*H*$_4$), 4.01 (m, 1 H, C$_5$*H*$_4$), 4.05 (m, 1 H, C$_5$*H*$_4$), 4.13 (s, 5 H, C$_5$*H*$_5$), 4.27 (m, 1 H, C$_5$*H*$_4$), 5.14 (m, 1 H, NC*H*), 6.26 (br. d, *J* = 10 Hz, 1 H, N*H*). − ^{13}C NMR (75 MHz, CDCl$_3$): δ = 14.36 (*C*H$_3$), 22.98 (*C*H$_2$), 23.17 (CO*C*H$_3$), 28.92 (*C*H$_2$), 36.80 (*C*H$_2$), 48.06 (*C*H), 66.74 (*C*$_5$H$_4$), 66.99 (*C*$_5$H$_4$), 67.56 (CDCl$_3$), 67.88 (*C*$_5$H$_4$), 69.06 (*C*$_5$H$_5$), 92.37 (*ipso-C*$_5$H$_4$), 168.58 (*C*O). − MS (70 eV); *m/z* (%): 313.1 (100) [M$^+$], 248.0 (32) [M$^+$ − C$_5$H$_5$]. − C$_{17}$H$_{23}$FeNO (313.11): calcd. C 65.19, H 7.40, N 4.47; found C 65.19, H 7.64, N 4.58.

(1R)-N-(1-Ferrocenyl-2,2-dimethylpropyl)acetamide [(1*R*)-**4d**]: 230 mg (0.60 mmol) of hydrazine (1*R*,2′*S*)-**3d** was cleaved according to GP3. The resulting (1-ferrocenyl-2,2-dimethylpropyl)amine was in situ protected with 0.11 ml of AcCl in the presence of Et$_3$N (2.5 equiv.) yielding 126 mg of (1*R*)-**4d** (67%) as yellow crystals. − [α]$_D^{22}$ = +89.7 (*c* = 1.0, C$_6$H$_6$). − IR (KBr): ṽ = 1643 cm^{-1} (s, CO). − ^{1}H NMR (300 MHz, CDCl$_3$): δ = 0.81 [s, 9 H, C(C*H*$_3$)$_3$], 2.16 (s, 3 H, CH$_3$), 3.93 (m, 1 H, C$_5$*H*$_4$), 4.09 (m, 1 H, C$_5$*H*$_4$), 4.12 (m, 1 H, C$_5$*H*$_4$), 4.13 (s, 5 H, C$_5$*H*$_5$), 4.19 (m, 1 H, C$_5$*H*$_4$), 4.68 (d, *J* = 10 Hz, 1 H, NC*H*), 5.90 (br. d, *J* = 10 Hz, 1 H, N*H*). − ^{13}C NMR (75 MHz, CDCl$_3$): δ = 23.67 (*C*H$_3$), 26.47 [C(*C*H$_3$)$_3$], 35.79 [*C*(CH$_3$)$_3$], 56.68 (*C*H), 64.95 (*C*$_5$H$_4$), 66.62 (*C*$_5$H$_4$), 67.26 (*C*$_5$H$_4$), 70.31 (*C*$_5$H$_4$), 68.64 (*C*$_5$H$_5$), 88.35 (*ipso-C*$_5$H$_4$), 168.73 (*C*O). − MS (70 eV); *m/z* (%): 313.0 (74) [M$^+$], 256.0 (91) [M$^+$ − C$_4$H$_9$], 214.0 (100) [C$_{11}$H$_{12}$FeN$^+$]. − C$_{17}$H$_{23}$FeNO (313.23): calcd. C 65.19, H 7.40, N 4.47; found C 65.49, H 7.39, N 4.37.

(1R)-N-(1-Ferrocenylheptyl)acetamide [(1*R*)-**4e**]: 160 mg (0.39 mmol) of hydrazine (1*R*,2′*S*)-**3e** was cleaved according to GP3. The resulting (1-ferrocenylheptyl)amine was in situ protected with 0.069 ml of AcCl in the presence of Et$_3$N (2.5 equiv.) yielding 106 mg of (1*R*)-**4e** (80%) as yellow crystals. − [α]$_D^{22}$ = −21.5 (*c* = 1.0, C$_6$H$_6$). − IR (KBr): ṽ = 1642 cm^{-1} (s, CO). − ^{1}H NMR (300 MHz, CDCl$_3$): δ = 0.88 (t, *J* = 7 Hz, 3 H, C*H*$_3$), 1.26−1.40 [m, 8 H, (C*H*$_2$)$_4$], 1.58 (m, 1 H, CHCH*H*), 1.81 (m, 1 H, CHC*H*H), 2.02 (s, 3 H, CH$_3$), 4.09−4.18 (m, 4 H, C$_5$*H*$_4$), 4.15 (s, 5 H, C$_5$*H*$_5$), 4.83 (m, 1 H, NC*H*), 5.63 (br. d, *J* = 9 Hz, 1 H, N*H*). − ^{13}C NMR (75 MHz, CDCl$_3$): δ = 14.10 (*C*H$_3$), 22.63 (*C*H$_2$), 23.56 (CO*C*H$_3$), 26.20 (*C*H$_2$), 29.24 (*C*H$_2$), 31.81 (*C*H$_2$), 36.11 (*C*H$_2$), 47.94 (*C*H), 66.90 (*C*$_5$H$_4$), 67.39 (*C*$_5$H$_4$), 67.78 (*C*$_5$H$_4$), 68.62 (*C*$_5$H$_5$), 91.30 (*ipso-C*$_5$H$_4$), 168.90 (*C*O). − MS (70 eV); *m/z* (%): 341.0 (100) [M$^+$], 276.0 (16) [M$^+$ − C$_5$H$_5$]. − C$_{19}$H$_{27}$FeNO (341.28): calcd. C 66.87, H 7.97, N 4.10; found C 66.71, H 7.63, N 4.05.

(1S)-N-(1-Ferrocenyl-1-phenylmethyl)acetamide [(1*S*)-**4f**]: 204 mg (0.50 mmol) of hydrazine (1*S*,2′*R*)-**3f** was cleaved according to GP3. The resulting (1-ferrocenyl-1-phenylmethyl)amine was in situ protected with 0.43 ml of AcCl in the presence of Et$_3$N (2.5 equiv.) yielding 117 mg of (1*S*)-**4f** (71%) as yellow crystals. − [α]$_D^{22}$ = +34.6 (*c* = 1.0, C$_6$H$_6$). − IR (KBr): ṽ = 1636 cm^{-1} (s, CO). − ^{1}H NMR (300 MHz, CDCl$_3$): δ = 2.01 (s, 3 H, C*H*$_3$), 4.02 (m, 1 H, C$_5$*H*$_4$), 4.09 (m, 1 H, C$_5$*H*$_4$), 4.13 (m, 1 H, C$_5$*H*$_4$), 4.14 (s, 5 H, C$_5$*H*$_5$), 4.15 (m, 1 H, C$_5$*H*$_4$), 5.96 (d, *J* = 9 Hz, 1 H, NC*H*), 6.42 (br. d, *J* = 9 Hz, 1 H, N*H*), 7.21−7.33 (m, 5 H, aromatic H). − ^{13}C NMR (75 MHz, CDCl$_3$): δ = 23.37 (*C*H$_3$), 52.22 (*C*H), 66.98 (*C*$_5$H$_4$), 67.59 (*C*$_5$H$_4$), 67.94 (*C*$_5$H$_4$), 68.79 (*C*$_5$H$_5$), 90.48 (*ipso-C*$_5$H$_4$), 127.02 (aromatic *C*), 127.28 (aromatic *C*), 128.31 (aromatic *C*), 142.08 (aromatic *C*), 168.54 (*C*O). − MS (70 eV); *m/z* (%): 333.2 (100) [M$^+$], 268.1 (28) [M$^+$ − C$_5$H$_5$]. − C$_{19}$H$_{19}$^{56}FeNO: calcd. 333.0816; found 333.0816 (HRMS).

(2′′S)-1,1′-Bis{[(2′′-methoxymethylpyrrolidin-1′′-yl)imino]methyl}ferrocene [(*S*,*S*)-**6**]: A mixture of ferrocene-1,1′-dicarbaldehyde (1.69 g, 6.98 mmol), 2 g of molecular sieves (4 Å), and SAMP (2.28 g, 17.5 mmol) in 40 ml of dry diethyl ether and 12 ml of dichloromethane was stirred at 0°C overnight and then diluted with ether (130 ml), dried with MgSO$_4$, and concentrated in vacuo. The crude product was purified by flash column chromatography (SiO$_2$, ether/petroleum ether, 1:6), yielding 3.23 g of (*S*,*S*)-**6** (99%) as a brown oil. − [α]$_D^{22}$ = +307.7 (*c* = 1.0, CHCl$_3$). − IR (CDCl$_3$): ṽ = 1582 cm^{-1} (s, C=N). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 1.52−1.85 (m, 8 H, C*H*$_2$C*H*$_2$), 2.71 (m, 2 H, NC*H*H), 3.18 (s, 6 H, OC*H*$_3$), 3.26 (m, 1 H, NCH*H*), 3.46 (d/d, *J* = 7/9 Hz, 2 H, C*H*$_2$O), 3.67 (m, 2 H, NC*H*CH$_2$), 3.75 (d/d, J = 3/9 Hz, 2 H, C*H*$_2$O), 4.11 (m, 4 H, C$_5$*H*$_4$), 4.61 (m, 2 H, C$_5$*H*$_4$), 4.71 (m, 2 H, C$_5$*H*$_4$), 7.05 (s, 2 H, NC*H*). − ^{13}C NMR (75 MHz, C$_6$D$_6$): δ = 22.38 (*C*H$_2$), 27.30 (*C*H$_2$), 49.22 (N*C*H$_2$), 58.90 (O*C*H$_3$), 63.51 (*C*H), 67.23 (*C*$_5$H$_4$), 67.84 (*C*$_5$H$_4$), 69.53 (*C*$_5$H$_4$), 69.58 (*C*$_5$H$_4$), 75.45 (*C*H$_2$O), 85.27 (*ipso-C*$_5$H$_4$), 132.10 (*C*=N). − MS (70 eV); *m/z* (%): 466.1 (100) [M$^+$], 223.9 (63) [C$_{12}$H$_{10}$FeN$^+$]. − C$_{17}$H$_{34}$FeN$_4$O$_2$ (466.41): calcd. C 61.81, H 7.35, N 12.01; found C 62.05, H 7.65, N 11.59.

(1′′R,2′′′S)-1,1′-Bis{1′′-[(2′′′-methoxymethylpyrrolidin-1′′′-yl)amino]ethyl}ferrocene [(1*R*,2′*S*)-**7a**]: 14.4 ml of a 1.6 M methyllithium solution (23 mmol) in diethyl ether and 1.03 g (2.21 mmol) of ferrocene-1,1′-dicarbaldehyde bis(SAMP hydrazone) [(*S*,*S*)-**6**] were allowed to react in 50 ml of dry diethyl ether according to GP2, yielding 904 mg of (1*R*,2′*S*)-**7a** (82%) as a brown oil. − [α]$_D^{22}$ = −174.0 (*c* = 0.25, CHCl$_3$). − IR (film): ṽ = 3089 cm^{-1} (m, NH). − ^{1}H NMR (300 MHz, C$_6$D$_6$): δ = 1.49 (d, *J* = 6 Hz, 6 H, C*H*$_3$), 1.40−2.05 (m, 10 H, NC*H*$_2$C*H*$_2$, NC*H*H), 2.52 (br. s, 2 H, N*H*), 2.77 (d/q, *J* = 4/8 Hz, 2 H, NC*H*), 3.23 (s, 6 H, OC*H*$_3$), 3.35−3.43 (m, 3 H, OCH*H*, NCH*H*), 3.78 (q, *J* = 6 Hz, 2 H, C*H*CH$_3$), 3.87 (d/d, *J* = 4/9 Hz, 2 H, OC*H*H), 4.01 (m, 2 H, C$_5$*H*$_4$), 4.03 (m, 2 H, C$_5$*H*$_4$), 4.10 (m, 2 H, C$_5$*H*$_4$), 4.26 (m, 2 H, C$_5$*H*$_4$). −

^{13}C NMR (75 MHz, C_6D_6): δ = 21.50 (CH_3), 22.51 (CH_2), 27.32 (CH_2), 53.08 (NCH_2), 56.97 ($CHCH_3$), 58.90 (OCH_3), 65.79 (NCH), 67.25 (C_5H_4), 67.36 (C_5H_4), 68.07 (C_5H_4), 68.27 (C_5H_4), 76.26 (CH_2O), 93.28 (*ipso*-C_5H_4). – MS (70 eV); *m/z* (%): 498.0 (8) [M$^+$], 239.2 (100) [$C_{13}H_{13}NFe^+$]. – $C_{26}H_{42}{}^{56}FeN_4O_2$: calcd. 498.2657; found 498.2657 (HRMS).

(1′′R,2′′′S)-1,1′-Bis{1′′-[(2′′′-methoxymethylpyrrolidin-1′′′-yl)amino]propyl}ferrocene [(1*R*,2′*S*)-**7b**]: Ethyllithium (1.32 ml of EtI, 22.0 ml of 1.6 M *t*BuLi)[1] and 1.12 g (2.4 mmol) of ferrocene-1,1′-dicarbaldehyde bis(SAMP hydrazone) [(*S*,*S*)-**6**] were allowed to react in 75 ml of dry diethyl ether according to GP2, yielding 1.16 g of (1*R*,2′*S*)-**7b** (92%) as a brown oil. – $[\alpha]_D^{22}$ = –152.4 (*c* = 0.25, $CHCl_3$). – IR (film): ṽ = 3087 cm^{-1} (w, NH). – ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.73 (t, *J* = 7 Hz, 6 H, CH_3), 0.80–2.22 (m, 14 H, CH_2, CH_2CH_3, NCHH), 2.64 (d/q, *J* = 3/8 Hz, 2 H, NCH), 2.76 (br. s, 2 H, NH), 3.38 (s, 6 H, OCH_3), 3.35–3.45 (m, 4 H, NCHH, NCH), 3.57 (m, 2 H, OCHH), 3.62 (d/d, *J* = 3/9, 2 H, OCHH), 4.02 (m, 2 H, C_5H_4), 4.06 (m, 2 H, C_5H_4), 4.09 (m, 2 H, C_5H_4), 4.16 (m, 2 H, C_5H_4). – ^{13}C NMR (75 MHz, $CDCl_3$): δ = 9.86 (CH_3), 21.01 (NCH_2CH_2), 25.93 ($NCHCH_2$), 28.57 (CH_2CH_3) 57.00 (NCH_2), 58.44 (CH), 59.12 (OCH_3), 65.84 (NCH), 65.97 (C_5H_4), 67.44 (C_5H_4), 67.78 (C_5H_4), 68.35 (C_5H_4), 74.70 (CH_2O), 91.69 (*ipso*-C_5H_4). – MS (70 eV); *m/z* (%): 526.2 (4) [M$^+$], 266.9 (100) [$C_{16}H_{19}Fe^+$]. – $C_{28}H_{46}{}^{56}FeN_4O_2$: calcd. 526.2970; found 526.2971 (HRMS).

(1′′R,2′′′S)-1,1′-Bis{1′′-[(2′′′-methoxymethylpyrrolidin-1′′′-yl)amino]butyl}ferrocene [(1*R*,2′*S*)-**7c**]: 20.3 ml of a 1.6 M *n*BuLi solution in *n*-hexane and 1.81 g (3.88 mmol) of ferrocene-1,1′-dicarbaldehyde bis(SAMP hydrazone) [(S,S)-**6**] were allowed to react in 80 ml of dry diethyl ether according to GP2, yielding 1.63 g of (1*R*,2′*S*)-**7c** (72%) as a brown oil. – $[\alpha]_D^{22}$ = –94.0 (*c* = 0.10, $CHCl_3$). – IR (film): ṽ = 3090 cm^{-1} (w, NH). – ^{1}H NMR (300 MHz, C_6D_6): δ = 0.90 (t, *J* = 7 Hz, 6 H, CH_3), 1.20–2.14 [m, 22 H, CH_2, $(CH_2)_3$, NCHH], 2.83 (d/q, *J* = 3/8 Hz, 2 H, NCH), 2.92 (br. s, 2 H, NH), 3.25 (s, 6 H, OCH_3), 3.46 (m, 2 H, NCHH), 3.47 (d/d, *J* = 8/9 Hz, 2 H, CH*n*Bu), 3.64 (d/d, *J* = 4/7 Hz, 2 H, OCHH), 3.89 (d/d, *J* = 3/9 Hz, 2 H, OCHH), 4.01 (m, 2 H, C_5H_4), 4.06 (m, 2 H, C_5H_4), 4.09 (s, 2 H, C_5H_4), 4.36 (m, 2 H, C_5H_4). – ^{13}C NMR (75 MHz, C_6D_6): δ = 14.46 (CH_3), 21.47 (NCH_2CH_2), 23.45 (CH_2), 27.15 ($NCHCH_2$), 28.17 (CH_2), 36.14 (CH_2), 56.92 (NCH_2), 57.55 (CH), 58.88 (OCH_3), 66.04 (NCH), 66.73 (C_5H_4), 67.89 (C_5H_4), 68.16 (C_5H_4), 68.50 (C_5H_4), 76.00 (CH_2O), 92.64 (*ipso*-C_5H_4). – MS (70 eV); *m/z* (%): 582.3 (3) [M$^+$], 323.0 (100) [$C_{20}H_{27}Fe^+$]. – $C_{32}H_{54}{}^{56}FeN_4O_2$: calcd. 582.3596; found 582.3597 (HRMS).

(1′′S,2′′′R)-1,1′-Bis{1′′-[(2′′′-methoxymethylpyrrolidin-1-yl)-amino]-2′′,2′′-dimethylpropyl}ferrocene [(1*S*,2′*R*)-**7d**]: 20 ml of a 1.6 M *t*BuLi solution in pentane and 1.79 g (3.84 mmol) of ferrocene-1,1-dicarbaldehyde bis(RAMP hydrazone) [(*R*,*R*)-**6**] were allowed to react in 80 ml of dry diethyl ether according to GP2, yielding 1.45 g of (1*S*,2′*R*)-**7d** (65%) as a brown oil. – $[\alpha]_D^{22}$ = –202.1 (*c* = 0.34, $CHCl_3$). – IR ($CHCl_3$): ṽ = 3090 cm^{-1} (m, NH). – ^{1}H NMR (300 MHz, C_6D_6): δ = 1.10 [s, 18 H, $C(CH_3)_3$], 1.50–2.00 [m, 12 H, $(CH_2)_2$, NCHH, NH], 2.67 (m, 2 H, NCH), 3.25 (s, 6 H, OCH_3), 3.36 [s, 2 H, C$H$$(CH_3)_3$], 3.51–3.60 (m, 4 H, NCHH, OCHH), 3.95 (m, 2 H, OCHH), 3.98 (m, 4 H, C_5H_4), 4.06 (m, 2 H, C_5H_4), 4.11 (m, 2 H, C_5H_4). – ^{13}C NMR (75 MHz, C_6D_6): δ = 21.16 (NCH_2CH_2), 26.95 ($NCHCH_2$), 28.42 [$C(CH_3)_3$], 35.63 [$C(CH_3)_3$], 55.94 (NCH_2), 58.82 (OCH_3), 64.19 (CH), 66.95 (C_5H_4), 67.35 (C_5H_4), 67.76 (C_5H_4), 68.43 (C_5H_4), 70.86 (NCH), 75.45 (CH_2O), 92.04 (*ipso*-C_5H_4). – MS (70 eV); *m/z* (%): 582.6 (14) [M$^+$], 525.5 (1) [M$^+$ – $C(CH_3)_3$], 319.2 (100) [$C_{16}H_{27}FeN_2O^+$]. – $C_{32}H_{54}{}^{56}FeN_4O_2$: calcd. 582.3596; found 582.3596 (HRMS).

(1′′R,2′′′S)-1,1′-Bis{1′′-[(2′′′-methoxymethylpyrrolidin-1′′′-yl)amino]hexyl}ferrocene [(1*R*,2′*S*)-**7e**]: 10.2 ml of a 2.0 M *n*HexLi solution in *n*-hexane and 946 mg (2.03 mmol) of ferrocene-1,1′-dicarbaldehyde bis(SAMP hydrazone) [(S,S)-**6**] were allowed to react in 50 ml of dry diethyl ether according to GP2, yielding 922 mg of (1*R*,2′*S*)-**7e** (71%) as a brown oil. – $[\alpha]_D^{22}$ = –101.2 (*c* = 0.25, $CHCl_3$). – IR (film): ṽ = 3091 cm^{-1} (w, NH). – ^{1}H NMR (300 MHz, C_6D_6): δ = 0.85 (t, *J* = 7 Hz, 6 H, CH_3), 1.18–2.14 [m, 30 H, $(CH_2)_5$, $(CH_2)_2$, NCHH], 2.84 (d/q, *J* = 4/8 Hz, 2 H, NCH), 2.98 (br. s, 2 H, NH), 3.27 (s, 6 H, OCH_3), 3.46 (m, 2 H, NCHH), 3.48 (d/d, *J* = 7/9, 2 H, CH), 3.66 (d/d, *J* = 4/7, 2 H, OCHH), 3.90 (d/d, *J* = 3/9, 2 H, OCHH), 3.98–4.18 (m, 8 H, C_5H_4). – ^{13}C NMR (75 MHz, C_6D_6): δ = 14.33 (CH_3), 21.47 (NCH_2CH_2), 23.10 (CH_2), 26.00 (CH_2), 27.19 ($NCHCH_2$), 30.15 (CH_2), 32.45 (CH_2), 36.48 (CH_2), 56.97 (NCH_2), 57.61 (CH), 58.92 (OCH_3), 66.07 (NCH), 66.76 (C_5H_4), 67.92 (C_5H_4), 68.19 (C_5H_4), 68.54 (C_5H_4), 76.08 (CH_2O), 92.69 (*ipso*-C_5H_4). – MS (70 eV); *m/z* (%): 637.9 (0.4) [M$^+$], 345.3 (100) [$C_{24}H_{35}Fe^+$]. – $C_{30}H_{47}{}^{56}FeN_2O^+$: calcd. 507.3038; found 507.3036 (HRMS).

(R,R)-1,1′-Bis(1-acetaminoethyl)ferrocene [(*R*,*R*)-**8a**]: 365 mg (0.73 mmol) of hydrazine (1*R*,2′*S*)-**7a** was cleaved according to GP3. The resulting (*R*,*R*)-1,1′-bis-(1-aminoethyl)ferrocene was in situ protected with 0.26 ml of AcCl in the presence of Et_3N (2.5 equiv.) yielding 178 mg of (*R*,*R*)-**8a** (69%) as yellow oil. – $[\alpha]_D^{22}$ = –30.8 (*c* = 0.25, $CHCl_3$). – IR ($CHCl_3$): ṽ = 1649 cm^{-1} (s, CO). – ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.44 (d, *J* = 7 Hz, 6 H, CH_3), 1.99 (s, 6 H, CH_3), 4.12 (m, 2 H, C_5H_4), 4.13 (m, 2 H, C_5H_4), 4.14 (m, 2 H, C_5H_4), 4.21 (m, 2 H, C_5H_4), 4.92 (d/q, *J* = 7/8 Hz, 2 H, NCH), 5.83 (br. d, *J* = 8 Hz, 2 H, NH). – ^{13}C NMR (75 MHz, $CDCl_3$): δ = 21.08 (CH_3), 23.48 ($COCH_3$), 43.80 (CH), 66.33 (C_5H_4), 67.91 (C_5H_4), 68.31 (C_5H_4), 68.89 (C_5H_4), 91.79 (*ipso*-C_5H_4), 168.90 (CO). – MS (70 eV); *m/z* (%): 356.2 (74) [M$^+$]. – $C_{18}H_{24}{}^{56}FeN_2O_2$: calcd. 356.1187; found 356.1185 (HRMS).

(R,R)-1,1′-Bis(1-acetaminopropyl)ferrocene [(*R*,*R*)-**8b**]: 269 mg (0.51 mmol) of hydrazine (1*R*,2′*S*)-**7b** was cleaved according to GP3. The resulting (*R*,*R*)-1,1′-bis(1-aminopropyl)ferrocene was in situ protected with 0.17 ml of AcCl in the presence of Et_3N (2.5 equiv.) yielding 137 mg of (*R*,*R*)-**8b** (70%) as yellow oil. – $[\alpha]_D^{22}$ = –22.7 (*c* = 0.25, $CHCl_3$). – IR (film): ṽ = 1651 cm^{-1} (s, CO). – ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.95 (t, *J* = 7 Hz, 6 H, CH_3), 1.60 (m, 2 H, CHH), 1.86 (m, 2 H, CHH), 2.05 (s, 6 H, CH_3), 4.04–4.17 (m, 8 H, C_5H_4), 4.78 (d/tr, *J* = 5/9 Hz, 2 H, NCH), 5.71 (br. d, *J* = 9 Hz, 2 H, NH). – ^{13}C NMR (75 MHz, $CDCl_3$): δ = 10.76 (CH_3), 23.52 ($COCH_3$), 29.23 (CH_2), 49.38 (CH), 66.95 (C_5H_4), 67.32 (C_5H_4), 68.23 (C_5H_4), 68.66 (C_5H_4), 91.45 (*ipso*-C_5H_4), 169.30 (CO). – MS (70 eV); *m/z* (%): 384.1 (27) [M$^+$]. – $C_{20}H_{28}{}^{56}FeN_2O_2$: 384.1500; found 384.1496 (HRMS).

(R,R)-1,1′-Bis(1-acetaminobutyl)ferrocene [(*R*,*R*)-**8c**]: 259 mg (0.45 mmol) of hydrazine (1*R*,2′*S*)-**7c** was cleaved according to GP3. The resulting (*R*,*R*)-1,1′-bis(1-aminobutyl)ferrocene was in situ protected with 0.26 ml of AcCl in the presence of Et_3N (2.5 equiv.) yielding 136 mg of (*R*,*R*)-**8c** (69%) as yellow oil. – $[\alpha]_D^{22}$ = –24.0 (*c* = 0.25, $CHCl_3$). – IR (film): ṽ = 1643 cm^{-1} (s, CO). – ^{1}H NMR (300 MHz, $CDCl_3$): δ = 0.90 (t, *J* = 7 Hz, 6 H, CH_3), 1.27–1.40 [m, 8 H, $(CH_2)_2$], 1.59 (m, 2 H, CHCHH), 1.77 (m, 2 H, CHCHH), 2.03 (s, 6 H, CH_3), 4.08 (m, 6 H, C_5H_4), 4.16 (m, 2 H, C_5H_4), 4.84 (d/tr, *J* = 5/9 Hz, 2 H, CH), 6.15 (br. d, *J* = 9 Hz, 2 H, NH). – ^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.07 (CH_3), 22.59 (CH_2), 23.41 ($COCH_3$), 28.43 (CH_2), 36.20 (CH_2), 47.88 (CH), 66.86 (C_5H_4), 67.33 (C_5H_4), 68.16 (C_5H_4), 68.56 (C_5H_4), 91.86 (*ipso*-C_5H_4), 169.29 (CO). – MS (70 eV); *m/z* (%): 440.0 (78) [M$^+$]. – $C_{24}H_{36}{}^{56}FeN_2O_2$: calcd. 440.2126; found 440.2127 (HRMS).

(S,S)-1,1′-Bis(1-acetamino-2,2-dimethylpropyl)ferrocene [(*S*,*S*)-**8d**]: 100 mg (0.17 mmol) of hydrazine (1*S*,2′*R*)-**7d** was cleaved according to GP3. The resulting (*R*,*R*)-1,1′-bis(1-amino-2,2-dimethylpropyl)ferrocene was in situ protected with 0.06 ml of AcCl in the presence of Et_3N (2.5 equiv.) yielding 44 mg of (*S*,*S*)-**8d** (58%) as yellow oil. − $[\alpha]_D^{22} = -35.4$ (c = 1.30, $CHCl_3$). − IR (KBr): $\tilde{\nu}$ = 1646 cm^{-1} (s, CO). − ^1H NMR (300 MHz, $CDCl_3$): δ = 0.79 [s, 18 H, $C(CH_3)_3$], 2.15 (s, 6 H, CH_3), 3.84 (m, 2 H, C_5H_4), 4.06 (m, 4 H, C_5H_4), 4.22 (m, 2 H, C_5H_4), 4.67 (d, J = 10 Hz, 2 H, C*H*), 6.12 (br. d, J = 10 Hz, 2 H, N*H*). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 23.68 (CH_3), 26.45 [$C(CH_3)_3$], 35.77 [$C(CH_3)_3$], 56.58 (CH), 65.08 (C_5H_4), 68.24 (C_5H_4), 68.47 (C_5H_4), 71.46 (C_5H_4), 88.74 (*ipso*-C_5H_4), 168.50 (CO). − MS (70 eV); *m/z* (%): 440.4 (86) [M^+], 383.3 (53) [$M^+ - C_4H_9$]. − $C_{24}H_{36}{}^{56}FeN_2O_2$: calcd. 440.2126; found 440.2127 (HRMS).

(R,R)-1,1′-Bis(1-acetaminoheptyl)ferrocene [(*R*,*R*)-**8e**]: 307 mg (0.48 mmol) of bishydrazine (1*R*,2′*S*)-**7e** was cleaved according to GP3. The resulting (*R*,*R*)-1,1′-bis-(1-aminoheptyl)ferrocene was in situ protected with 0.22 ml of AcCl in the presence of Et_3N (2.5 equiv.) yielding 125 mg of (*R*,*R*)-**8e** (53%) as yellow oil. − $[\alpha]_D^{22}$ = -20.0 (c = 0.35, $CHCl_3$). − IR ($CHCl_3$): $\tilde{\nu}$ = 1646 cm^{-1} (s, CO). − ^1H NMR (300 MHz, $CDCl_3$): δ = 0.88 (t, J = 7 Hz, 6 H, CH_3), 1.24−1.37 [m, 16 H, $(CH_2)_4$], 1.58 (m, 2 H, CHC*H*H), 1.78 (m, 2 H, CHCH*H*), 2.04 (s, 6 H, CH_3), 4.10 (m, 6 H, C_5H_4), 4.13 (m, 2 H, C_5H_4), 4.85 (d/tr, J = 5/9 Hz, 2 H, C*H*), 5.79 (br. d, J = 9 Hz, 2 H, N*H*). − ^{13}C NMR (75 MHz, $CDCl_3$): δ = 14.09 (CH_3), 22.63 (CH_2), 23.50 ($COCH_3$), 26.21 (CH_2), 29.23 (CH_2), 31.81 (CH_2), 36.40 (CH_2), 47.94 (CH), 66.97 (C_5H_4), 67.27 (C_5H_4), 68.19 (C_5H_4), 68.65 (C_5H_4), 91.77 (*ipso*-C_5H_4), 169.24 (CO). − MS (70 eV); *m/z* (%): 496.0 (7) [M^+]. − $C_{28}H_{44}{}^{56}FeN_2O_2$: calcd. 496.2752; found 496.2754 (HRMS).

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[1] R. Herrmann, G. Hübener, F. Siglmüller, I. Ugi, *Liebigs Ann. Chem.* **1986**, 251.

[2] M. Cushman, J.-K. Chen, *J. Org. Chem.* **1987**, *52*, 1517.

[3] [3a] T. Hayashi, K. Yamamoto, M. Kumada, *Tetrahedron Lett.* **1974**, 4405. − [3b] T. Hayashi, K. Yamamoto, T. Hagihara, Y. Ito, *Tetrahedron Lett.* **1986**, *27*, 191. − [3c] T. Hayashi, M. Konishi, Y. Okamoto, K. Kabeta, M. Kumada, *J. Org. Chem.* **1986**, *51*, 3772. − [3d] M. Sawamura, Y. Ito, *Chem Rev.* **1992**, *92*, 857. − [3e] T. Hayashi, A. Katsumura, M. Konishi, M. Kumada, *Tetrahedron Lett.* **1979**, *20*, 425. − [3f] A. Schnyder, L. Hintermann, A. Togni, *Angew. Chem.* **1995**, *107*, 996; *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 931 − [3g] A. Togni, U. Burckhardt, V. Gramlich, P. S. Pregosin, R. Salzmann, *J. Am. Chem. Soc.* **1996**, *118*, 1031.

[4] G. Gokel, D. Marquarding, I. Ugi, *J. Org. Chem.* **1972**, *37*, 3052.

[5] [5a] D. Marquarding, H. Klusacek, G. Gokel, P. Hoffmann, I. Ugi, *J. Am. Chem. Soc.* **1970**, *92*, 5389. − [5b] S. Bhattacharyya, *Synth. Commun.* **1994**, *24*, 2713. − [5c] N.W. Boaz, *Tetrahedron Lett.* **1989**, *30*, 2061. − [5d] R. Herrmann, I. Ugi, *Tetrahedron* **1981**, *37*, 1001. − [5e] C. R. Lindsay, J. K. Hauser, *J. Organomet. Chem.* **1977**, *136*, 57. − [5f] G. W. Gokel, I. Ugi, *J. Chem. Educ.* **1972**, *49*, 292.

[6] D. M. David, L. A. P. Kane-Maguire, S. G. Pyne, *J. Chem. Soc., Chem. Commun.* **1990**, 888.

[7] Y. Matsumoto, A. Ohne, S. Lu, T. Hayashi, N. Oguni, M. Hayashi, *Tetrahedron: Asymmetry* **1996**, *7*, 2509.

[8] W. F. Baily, E. R. Punzalan, *J. Org. Chem.* **1990**, *55*, 5404.

[9] T. Hayase, Y. Inoue, T. Shibata, K. Soai, *Tetrahedron: Asymmetry* **1996**, *7*, 2509.

[10] [10a] A. Ohne, M. Yamane, T. Hayashi, N. Oguni, M. Hayashi, *Tetrahedron: Asymmetry* **1995**, *6*, 2495. − [10b] J. Wright, L. Frambes, P. Reeves, *J. Organomet. Chem.* **1994**, *476*, 215. − [10c] L. Schwink, P. Knochel, *Tetrahedron Lett.*, **1996**, *37*, 35.

[11] [11a] A. Togni, *Angew. Chem.* **1996**, *108*, 1581; *Angew. Chem. Int. Ed. Engl.* **1996**, *35*, 1475 − [11b] J. McGarrity, F. Spindler, R. Fuchs, M. Eyer (LONZA AG), EP-A 624 587 A2, **1995** [*Chem. Abstr.* **1995**, *122*, P81369q]. − [11c] A. Togni, *Chimia* **1996**, *50*, 86.

[12] T. Hayashi, A. Yamamoto, M. Hojo, K. Kishi, Y. Ito, E. Nishioka, H. Miura, K. Yanagi, *J. Organomet. Chem.* **1989**, *370*, 129.

[13] K. Soai, T. Hayase, K. Takai, T. Sugiyama, *J. Org. Chem.* **1994**, *59*, 7908.

[14] M. Watanabe, *Tetrahedron Lett.* **1995**, *36*, 8991.

[15] L. Schwink, P. Knochel, *Tetrahedron Lett.* **1996**, *37*, 25.

[16] H. C. L. Abbenhuis, U. Burckhardt, V. Gramlich, A. Togni, A. Albinati, B. Müller, *Organometallics* **1994**, *13*, 4481.

[17] L. Schwink, S. Vettel, P. Knochel, *Organometallics* **1995**, *14*, 5000.

[18] L. Schwink, P. Knochel, *Tetrahedron Lett.* **1996**, *37*, 8165.

[19] D. Enders, R. Lochtman, G. Raabe, *Synlett* **1996**, 126.

[20] C. Nübling, Dissertation, Technical University of Aachen, **1987**.

[21] [21a] N. R. Natale, *Tetrahedron Lett.* **1982**, *23*, 5009. − [21b] J. L. Namy, J. Souppe, J. Collin, H. B. Kagan, *J. Org. Chem.* **1984**, *49*, 2045. − [21c] H. B. Kagan, J. L. Namy, *Tetrahedron* **1986**, *42*, 6573. − [21d] J. Souppe, L. Danon, J. L. Namy, H. B. Kagan, *J. Organomet. Chem.* **1983**, *250*, 227. − [21e] M. J. Burk, J. P. Martinez, J. E. Feaster, N. Cosford, *Tetrahedron* **1994**, *50*, 4399. − [21f] M. J. Burk, J. E. Feaster, *J. Am. Chem. Soc.* **1992**, *114*, 6266.

[22] D. A. Claremon, P. K. Lumma, B. T. Phillips, *J. Am. Chem. Soc.* **1986**, *108*, 8265.

[23] [23a] D. Enders, H. Schubert, C. Nübling, *Angew. Chem.* **1986**, *98*, 1118; *Angew. Chem. Int. Ed. Engl.* **1986**, *25*, 1109. − [23b] D. Enders, J. Tiebes, *Liebigs Ann. Chem.* **1993**, 173. − [23c] D. Enders, M. Klatt, R. Funk, *Synlett* **1993**,226. − [23d] D. Enders, R. Funk, M. Klatt, G. Raabe, E.R. Hovestreydt, *Angew. Chem.* **1993**, *105*, 418; *Angew. Chem. Int. Ed. Engl.* **1993**, *32*, 418. − [23e] D. Enders, J. Schankat, M. Klatt, *Synlett* **1994**, 1322. − [23f] D. Enders, U. Reinold, *Angew. Chem.* **1995**, *107*, 1332; *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 1219. − [23g] D. Enders, H. Schubert, *Angew. Chem.* **1984**, *96*, 368; *Angew. Chem. Int. Ed. Engl.* **1984**, *23*, 365. − [23h] D. Enders, J. Tiebes, Dissertation, Technical University of Aachen, **1993**. − [23i] Autorenkollektiv, *Organikum*, VEB Deutscher Verlag der Wissenschaften, 16th edition, Berlin, **1986**. − [23j] R. Mozingo, *Org. Synth. Coll.* **1955**, *Vol. III*, 181.

[24] Details of the X-ray structure analysis of (*S*,*R*)-**3d** may be obtained from the Fachinformationszentrum Karlsruhe, D-76344 Eggenstein-Leopoldshafen, Germany, upon quoting the depository number CSD-59185, the names of the authors, and the journal citation.

[25] M. A. Carroll, D. A. Widdowson, D. J. Williams, *Synlett* **1994**, 1025.

[26] D. Enders, R. Lochtman, *Synlett* **1997**, 355.

[27] [27a] J. A. Dale, H. S. Mosher, *J. Org. Chem.* **1969**, *34*, 2543. − [27b] J. A. Dale, H. S. Mosher, *J. Am. Chem. Soc.* **1973**, *95*, 512.

[28] Details of the X-ray structure analysis of (*S*)-**2** may be obtained from the Fachinformationszentrum Karlsruhe, D-76344 Eggenstein-Leopoldshafen, Germany, upon quoting the depository number CSD-59185, the names of the authors, and the journal citation.

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