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Stereoselective cyanation of chiral α-amino aldehydes by reaction with Nagata's reagent: a route to enantiopure β-amino-α-hydroxy acids

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Abstract—Chiral α-dibenzylamino aldehydes react with diethylaluminum cyanide leading to *anti*-β-dibenzylamino-α-hydroxy-cyanides as the major diastereoisomers in good yields and diastereomeric excesses. Hydrolysis of the nitrile derivatives allows the synthesis of enantiopure β-amino-α-hydroxy acids. © 2001 Elsevier Science Ltd. All rights reserved.

1. Introduction

β-Amino-α-hydroxy acids are of great interest because they are starting materials in the synthesis of β-lactam antibiotics[1] and constituents of biologically active peptides. For example, (2*S*,3*R*)-3-amino-2-hydroxy-4-phenylbutanoic acid (AHPBA) is a component of bestatin,[2] a dipeptide inhibitor of aminopeptidase B and leucine aminopeptidase.[3] (2*S*,3*R*)-3-Amino-2-hydroxy-5-methylhexanoic acid (AHMHA) is a constituent in amastatine,[4] whereas (2*R*,3*S*)-3-phenylisoserine is the amino acid present at the lateral chain of taxol.[5] Because of this occurrence in drugs and natural products many different methods have been directed into the stereoselective synthesis of these compounds.[6,7]

Cyanohydrins prepared from protected α-amino aldehydes have been used as key intermediates in the synthesis of β-amino-α-hydroxy acids. Thus, 2-*N*-benzyloxycarbonylamino aldehydes were transformed stereoselectively into cyanohydrins by reaction with trimethylsilyl cyanide[8] (TMSCN) or tributyltin cyanide[9] in good yields and with moderate *threo*-selectivity. The diastereoselective addition of TMSCN to *N*,*N*-dibenzylamino aldehydes has also been tested in the presence of Lewis acids,[10] and it is interesting that the nature of the acid directs the stereochemistry of the reaction. The *syn*-adducts were formed when $MgBr_2$ or $TiCl_4$ were used, whereas the *anti*-addition products were obtained as major diastereoisomers when using $ZnBr_2$, BF_3 or $SnCl_4$ as the Lewis acid. Very good *anti*-stereoselectivities (90–93%) were observed in the cyanation of α-amino aldehyde derivatives with acetone cyanohydrin in the presence of trimethylaluminum or ethylaluminum dichloride as Lewis acids.[11]

Previously, we have reported[12,13] that diethylzinc reacts with α-dibenzylamino aldehydes with excellent stereoselectivities leading to *syn*-adducts as the major stereoisomers, as an alternative to the use of other organometallic reagents.[14] Herein, we report on the diastereoselective cyanation of chiral α-amino aldehydes with diethylaluminum cyanide, because Nagata's reagent behaves not only as a good cyanating agent but also as a Lewis acid with the possibility of reacting after coordination to the heteroatoms in the starting α-amino aldehyde.

The reaction of α-dibenzylamino aldehydes **1a**–**f**[12] with diethylaluminum cyanide (1.1 equiv.) in toluene at −78°C led, after hydrolysis, to a mixture of epimeric cyanohydrins *anti*- and *syn*-**2a**–**f** in good yields and diastereomeric excesses (Scheme 1 and Table 1). The best diastereoselection (82:18) was obtained for the cyanation of the L-valine derivative **1b** whereas the addition to the (*R*)-2-phenylglycine derivative *ent*-**1e** yielded a mixture of diastereomers *ent*-**2e** in very low d.e. (entry 6). It is also noteworthy that the presence of an additional heteroatom β- to the aldehyde carbonyl in the L-serine derivative **1f** did not affect the facial discrimination. The *anti*-addition products were always

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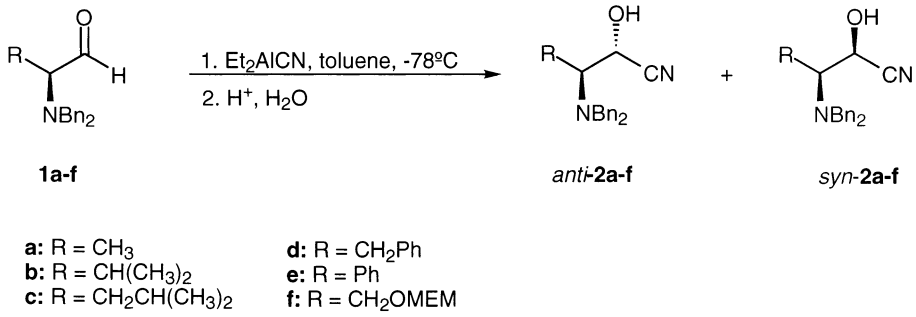


Scheme 1.

Table 1. Stereoselective addition of Et_2AlCN to *N*,*N*-dibenzylamino aldehydes **1a**–**f**

Entry	Aldehyde	Time (h)	Yield (%)[a]	**2**	*anti*:*syn*[b]
1	**1a**	2	79	**2a**	79:21
2	**1a**	2	78	**2a**	80:20[c]
3	**1b**	2	72	**2b**	82:18
4	**1c**	2	80	**2c**	70:30
5	**1d**	2	84	**2d**	75:25
6	*ent*-**1e**	2	85	*ent*-**2e**	58:42
7	**1f**	2	72	**2f**	80:20

[a] Combined yield of diastereomers after purification by flash chromatography.
[b] Determined by ^1H NMR analysis of the crude of the reactions.
[c] Reaction performed with 2 equiv. of Nagata's reagent.

obtained as major diastereoisomers, showing that the reaction occurred with a non-chelated intermediate in agreement with the Felkin–Ahn model previously reported.[14] This was also observed when 2 equiv. of diethylaluminum cyanide were used or when Lewis acids such as $MgBr_2$ or $ZnBr_2$ were added prior to the reaction with Nagata's reagent; only in the case of addition of $TiCl_4$ was a decrease in the stereoselection observed, although the *anti*-diastereoisomers were obtained as the predominant products.

Diastereomeric cyanohydrins *syn*- and *anti*-**2a**–**f** were easily separated by flash chromatography on silica gel using hexane–dichloromethane eluent mixtures. The stereochemistry for *syn*- and *anti*-**2a** was assigned by comparison of its ^1H NMR data with that described in the literature.[10] In this way, the vicinal coupling constant ($J_{1,3}$) between C-(2)H and C-(3)H is higher for *syn*-**2a** than for *anti*-**2a**, and this fact is general for *syn*- and *anti*-**2b**–**e** and related compounds.[15,16]

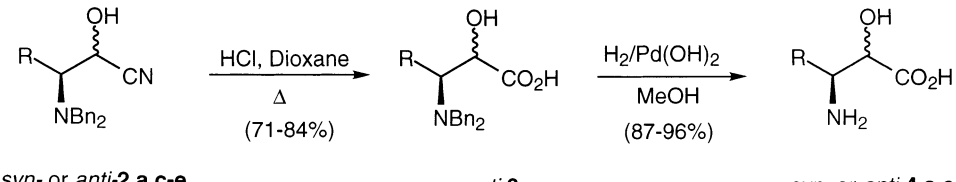
The stereochemistry for all diastereoisomers was initially assigned on the basis of this data, and finally confirmed by chemical correlation. To this end, after isolation, *syn*- and *anti*-**2a**,**c**–**e** were transformed into the known β-amino-α-hydroxy acids over two steps and in good yields. Treatment of the cyanohydrins with concentrated hydrochloric acid in dioxane at reflux[7a] gave the corresponding β-dibenzylamino-α-hydroxy acid derivatives *syn*- and *anti*-**3a**,**c**–**e**, which were debenzylated by hydrogenolysis (under hydrogen at atmospheric pressure with palladium hydroxide in methanol at rt) to afford enantiopure *syn*- and *anti*-**4a**,**c**–**e** (Scheme 2).

In summary, this work demonstrates that diethylaluminum cyanide (Nagata's reagent) is a good cyanating agent and is capable of reacting with chiral α-dibenzylamino aldehydes to afford the corresponding β-dibenzylamino-α-hydroxynitriles in good yields and diastereomeric excesses. The stereochemistry of the predominant *anti*-product can be explained in agreement with the Felkin–Ahn non-chelation model.

2. Experimental

2.1. General

The reactions were carried out in oven-dried glassware, under an argon atmosphere, using anhydrous solvents. Starting aminoaldehydes **1** were prepared as previously



Scheme 2.

described.[12] Diethylaluminum cyanide, as a 1 M solution in toluene, was purchased from Aldrich. The ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectra were recorded on Bruker AC 300 or AMX 300 spectrometers, using TMS as internal standard. IR spectra were recorded on a Philips PU 9706 spectrometer, as a film or in a Nujol dispersion. Mass spectra were performed by chemical ionisation (CI). Optical rotations were measured on a Perkin–Elmer 241 polarimeter in a 1 dm cell. Microanalyses were performed with a Perkin–Elmer 2400-CHN elemental analyser.

2.2. Reaction of amino aldehydes 1 with Et_2AlCN: general method

To a solution of amino aldehyde **1** (1 mmol) in anhydrous toluene (8 mL) at −78°C under argon was added dropwise a 1 M solution of diethylaluminum cyanide in toluene (1.1 mL, 1.1 mmol, 1.1 equiv.). The mixture was stirred at that temperature until the reaction was finished (TLC), and then quenched with a solution of aqueous saturated ammonium chloride (10 mL). The organic layer was separated and the aqueous phase was extracted with diethyl ether (2×10 mL). The combined organic layers were washed with brine, and dried over anhydrous Na_2SO_4. The solvent was removed under vacuum and the residue was purified by flash chromatography (silica gel, hexane–dichloromethane).

2.3. (2*R*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxybutanenitrile *syn*-2a[10]

Colorless oil. $[\alpha]_D^{23}=+90.3$ ($c=1.1$, $CHCl_3$). IR (film): 3400, 2240 cm^{-1}. ^{1}H NMR ($CDCl_3$): 1.23 (d, 3H, $J=6.8$ Hz, C$\underline{H}_3$), 3.09 (dq, 1H, $J=10.1$ Hz, $J=6.7$ Hz, C$\underline{H}$N), 3.38 (d, 2H, $J=13.2$ Hz, CH$\underline{H}$N), 3.73 (d, 2H, C$\underline{H}$HN, $J=13.2$ Hz), 4.12 (d, 1H, C$\underline{H}$OH, $J=10.1$ Hz), 4.25 (br s, 1H, O$\underline{H}$), 7.20–7.40 (m, 10H, $\underline{H}_{arom.}$). ^{13}C NMR ($CDCl_3$): 8.6 ($\underline{C}H_3$), 53.1 (N$\underline{C}H_2$), 57.0 ($\underline{C}$HN), 61.9 ($\underline{C}$HOH), 118.9 ($\underline{C}$N), 127.7, 128.7, 128.9 ($\underline{C}H_{arom.}$), 137.5 ($\underline{C}_{arom.}$). MS (CI), m/z (%): 281 (M$^+$+1, 20), 254 (100), 224 (44).

2.4. (2*S*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxybutanenitrile *anti*-2a[10]

Colorless solid. Mp 89–90°C (from hexane–ethyl acetate). $[\alpha]_D^{23}=+24.7$ ($c=0.9$, $CHCl_3$). IR (film): 3400, 2260 cm^{-1}. ^{1}H NMR ($CDCl_3$): 1.28 (d, 3H, $J=6.9$ Hz, C$\underline{H}_3$), 3.14 (m, 1H, C$\underline{H}$N), 3.40 (d, 2H, $J=13.2$ Hz, C$\underline{H}$HN), 4.04 (d, 2H, $J=13.2$ Hz, CH$\underline{H}$N), 4.17 (d, 1H, $J=6.3$ Hz, C$\underline{H}$OH), 4.42 (br s, 1H, O$\underline{H}$), 7.20–7.40 (m, 10H, $\underline{H}_{arom.}$). ^{13}C NMR ($CDCl_3$): 8.9 ($\underline{C}H_3$), 53.5 (N$\underline{C}H_2$), 54.5 ($\underline{C}$HN), 62.2 ($\underline{C}$HOH), 119.4 ($\underline{C}$N), 127.6, 128.6, 129.0 ($\underline{C}H_{arom.}$), 138.0 ($\underline{C}_{arom.}$); MS (CI), m/z (%): 282 (M$^+$+2, 29), 254 (100), 224 (29), 210 (31), 107 (44).

2.5. (2*R*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-4-methylpentanenitrile *syn*-2b

Colorless oil. $[\alpha]_D^{23}=+15.8$ ($c=1.2$, $CHCl_3$). IR (film): 3420, 2250 cm^{-1}. ^{1}H NMR ($CDCl_3$): 1.11 (d, 3H, $J=6.9$ Hz, C$\underline{H}_3$), 1.21 (d, 3H, $J=6.9$ Hz, C$\underline{H}_3$), 2.31 (m, 1H, $(CH_3)_2C\underline{H}$), 2.81 (dd, 1H, $J=5.8$ Hz, $J=8.4$ Hz, C$\underline{H}$N), 3.63 (d, 2H, $J=13.2$ Hz, CH$\underline{H}$N), 3.82 (d, 2H, $J=13.2$ Hz, C$\underline{H}$HN), 4.29 (br s, 1H, O$\underline{H}$), 4.36 (d, 1H, $J=8.4$ Hz, C$\underline{H}$OH), 7.20–7.40 (m, 10H, $\underline{H}_{arom.}$). ^{13}C NMR ($CDCl_3$): 19.7 ($\underline{C}H_3$), 22.4 ($\underline{C}H_3$), 27.2 ($(CH_3)_2\underline{C}H$), 54.0 ($\underline{C}H_2$N), 58.8 ($\underline{C}$HN), 65.4 ($\underline{C}$HOH); 120.0 ($\underline{C}$N), 127.5, 128.5, 129.1 ($\underline{C}H_{arom.}$), 138.0 ($\underline{C}_{arom.}$). MS (CI), m/z (%): 309 (M$^+$+1, 53), 282 (100), 252 (97). Anal. calcd for $C_{20}H_{24}N_2O$: C, 77.89; H, 7.84; N, 9.08. Found: C: 77.72; H, 7.70; N, 9.03%.

2.6. (2*S*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-4-methylpentanenitrile *anti*-2b

Colorless oil. Mp 83–84°C (from hexane–ethyl acetate). $[\alpha]_D^{23}=-49.5$ ($c=1.0$, $CHCl_3$). IR (Nujol): 3260, 2200 cm^{-1}. ^{1}H NMR ($CDCl_3$): 0.97 (d, 3H, $J=6.5$ Hz, C$\underline{H}_3$), 1.34 (d, 3H, $J=6.5$ Hz, C$\underline{H}_3$), 2.46 (m, 1H, $(CH_3)_2C\underline{H}$), 2.66 (dd, 1H, $J=5.6$ Hz, $J=10.8$ Hz, C$\underline{H}$N), 3.73 (d, 2H, $J=13.0$ Hz, CH$\underline{H}$N), 4.19 (d, 2H, $J=13.0$ Hz, C$\underline{H}$HN), 4.25 (dd, 1H, $J=5.6$ Hz, $J=9.2$ Hz, C$\underline{H}$OH), 4.64 (d, 1H, $J=9.2$ Hz, O$\underline{H}$), 7.15–7.40 (m, 10H, $\underline{H}_{arom.}$). ^{13}C NMR ($CDCl_3$): 20.1 ($\underline{C}H_3$), 22.4 ($\underline{C}H_3$), 28.9 ($(CH_3)_2\underline{C}H$), 55.0 (N$\underline{C}H_2$), 59.3 ($\underline{C}$HN), 64.7 ($\underline{C}$HOH), 119.5 ($\underline{C}$N), 127.7, 128.7, 129.5 ($\underline{C}H_{arom.}$), 138.2 ($\underline{C}_{arom.}$). MS (CI), m/z (%): 310 (M$^+$+2, 9), 382 (100), 252 (51). Anal. calcd for $C_{20}H_{24}N_2O$: C, 77.89; H, 7.84; N, 9.08. Found: C 77.69; H, 7.73; N, 9.14%.

2.7. (2*R*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-5-methylhexanenitrile *syn*-2c

Colorless oil. $[\alpha]_D^{23}=+45.5$ ($c=1.1$, $CHCl_3$). IR (film): 3400, 2240 cm^{-1}. ^{1}H NMR ($CDCl_3$): 0.92 (d, 3H, $J=6.5$ Hz, C$\underline{H}_3$), 0.96 (d, 3H, $J=6.5$ Hz, C$\underline{H}_3$), 1.37 (m, 1H, (C$\underline{H}$HCH), 1.70 (m, 1H, CH$\underline{H}$CH), 1.93 (m, 1H, $(CH_3)_2C\underline{H}$), 3.03 (m, 1H, C$\underline{H}$N), 3.53 (d, 2H, $J=13.3$ Hz, CH$\underline{H}$N), 3.76 (d, 2H, $J=13.3$ Hz, C$\underline{H}$HN), 4.15 (d, 1H, $J=8.9$ Hz, C$\underline{H}$OH), 4.30 (br s, 1H, O$\underline{H}$), 7.20–7.40 (m, 10H, $\underline{H}_{arom.}$). ^{13}C NMR ($CDCl_3$): 22.7 ($\underline{C}H_3$), 22.8 ($\underline{C}H_3$), 25.3 ($(CH_3)_2\underline{C}H$), 35.8 ($\underline{C}H_2$CH), 53.8 ($\underline{C}H_2$N), 58.6 ($\underline{C}$HN), 61.6 ($\underline{C}$HOH), 119.5 ($\underline{C}$N), 127.6, 128.6, 129.0 ($\underline{C}H_{arom.}$), 138.0 ($\underline{C}_{arom.}$). MS (CI), m/z (%): 324 (M$^+$+2, 11), 296 (100), 266 (43). Anal. calcd for $C_{21}H_{26}N_2O$: C, 78.22; H, 8.13; N, 8.69. Found: C, 78.44; H, 8.32; N, 8.64%.

2.8. (2*S*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-5-methylhexanenitrile *anti*-2c

Colorless oil. $[\alpha]_D^{23}=+23.3$ ($c=1.0$, $CHCl_3$). IR (film): 3400, 2260 cm^{-1}. ^{1}H NMR ($CDCl_3$): 0.89 (d, 3H, $J=6.3$ Hz, C$\underline{H}_3$), 1.00 (d, 3H, $J=6.3$ Hz, C$\underline{H}_3$), 1.58 (m, 1H, $(CH_3)_2C\underline{H}$), 1.70 (m, 2H, $C\underline{H}_2$CH), 3.04 (m, 1H, C$\underline{H}$N), 3.41 (d, 2H, $J=13.2$ Hz, CH$\underline{H}$N), 4.05 (d, 2H, $J=13.2$ Hz, C$\underline{H}$HN), 4.26 (d, 1H, $J=5.8$ Hz, C$\underline{H}$OH), 4.71 (br s, 1H, O$\underline{H}$), 7.20–7.40 (m, 10H, $\underline{H}_{arom.}$). ^{13}C NMR ($CDCl_3$): 21.7 ($\underline{C}H_3$), 23.8 ($\underline{C}H_3$), 24.8 ($(CH_3)_2\underline{C}H$), 33.7 ($\underline{C}H_2$CH), 54.2 ($\underline{C}H_2$N), 56.5 ($\underline{C}$HN), 60.0 ($\underline{C}$HOH),

119.3 (CN), 127.7, 128.7, 129.2 ($CH_{arom.}$), 138.0 ($C_{arom.}$). MS (CI), m/z (%): 324 (M^++2, 10), 296 (100), 266 (38). Anal. calcd for $C_{21}H_{26}N_2O$: C, 78.22; H, 8.13; N, 8.69. Found: C, 78.40; H, 8.26; N, 8.61%.

2.9. (2*R*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-4-phenylbutanenitrile *syn*-2d

Colorless solid. Mp 110–111°C (from hexane–ethyl acetate). $[\alpha]_D^{23}=+46.8$ ($c=1.0$, $CHCl_3$) [Lit.[11] $[\alpha]_D^{23}=+47.9$ ($c=1.05$, $CHCl_3$)]. IR (Nujol): 3400, 2250 cm^{-1}. ^1H NMR ($CDCl_3$): 2.96 (dd, 1H, $J=13.9$ Hz, $J=6.3$ Hz, PhCHHCH), 3.08 (dd, 1H, $J=13.9$ Hz, $J=7.8$ Hz, PhCHHCH), 3.28 (m, 1H, CHN), 3.44 (d, 2H, $J=13.3$ Hz, CHHN), 3.85 (d, 2H, $J=13.3$ Hz, CHHN), 3.93 (br s, 1H, OH), 4.23 (d, 1H, $J=8.5$ Hz, CHOH), 7.10–7.40 (m, 15H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 32.1 ($PhCH_2CH$), 54.1 (NCH_2), 61.7 (CHN), 62.3 (CHOH), 119.1 (CN), 126.9, 127.6, 128.6, 128.8, 128.9, 129.3 ($C_{arom.}$), 137.9 ($C_{arom.}$), 138.0 ($C_{arom.}$). MS (CI), m/z (%): 358 (M^++2, 13), 330 (100), 300 (33), 238 (24).

2.10. (2*S*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-4-phenylbutanenitrile *anti*-2d

Colorless solid. Mp 98–99°C (from hexane–ethyl acetate) [Lit.[11] mp 98°C (CH_2Cl_2–hexane)]. $[\alpha]_D^{23}$ +48.0 ($c=1.0$, $CHCl_3$) [Lit.[11] $[\alpha]_D^{23}=+49.4$ ($c=1.01$, $CHCl_3$)]. IR (Nujol): 3400, 2220 cm^{-1}. ^1H NMR ($CDCl_3$): 2.93 (dd, 1H, $J=9.8$ Hz, $J=12.5$ Hz, PhCHHCH), 3.25 (m, 2H, PhCHHCH, CHN), 3.56 (d, 2H, $J=13.2$ Hz, CHHN), 4.02 (d, 1H, $J=5.2$ Hz, CHOH), 4.24 (d, 2H, $J=13.2$ Hz, CHHN), 4.51 (br s, 1H, OH), 7.20–7.40 (m, 15H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 31.2 ($PhCH_2CH$), 54.4 (CH_2N), 59.5 (CHN), 61.0 (CHOH), 119.4 (CN), 127.0, 127.8, 128.8, 128.9, 129.0, 129.2 ($C_{arom.}$), 136.7 ($C_{arom.}$), 137.7 ($C_{arom.}$). MS (CI), m/z (%): 358 (M^++2, 13), 330 (100), 300 (27), 238 (25).

2.11. (2*S*,3*R*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-3-phenylpropanenitrile *ent-syn*-2e

Colorless oil. $[\alpha]_D^{23}=-139.7$ ($c=1.0$, $CHCl_3$). IR (film): 3380, 2250 cm^{-1}. ^1H NMR ($CDCl_3$): 3.13 (d, 2H, $J=13.2$ Hz, NCHHN), 3.85 (d, 2H, $J=13.2$ Hz, CHHN), 4.04 (d, 1H, $J=10.7$ Hz, CHN), 4.32 (br s, 1H, OH), 4.89 (d, 1H, $J=10.7$ Hz, CHOH), 7.20–7.55 (m, 15H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 53.5 (NCH_2), 59.8 (CHN), 65.3 (CHOH), 118.5 (CN), 127.9, 129.0, 129.1, 129.3, 129.5 ($C_{arom.}$), 131.2 ($C_{arom.}$), 137.8 ($C_{arom.}$). MS (CI), m/z (%): 344 (M^++2, 14), 316 (100), 286 (19). Anal. calcd for $C_{23}H_{22}N_2O$: C, 80.67; H, 6.47; N, 8.18. Found: C: 80.46; H, 6.30; N, 8.20%.

2.12. (2*R*,3*R*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-3-phenylpropanenitrile *ent-anti*-2e

Colorless oil. $[\alpha]_D^{23}=-81.6$ ($c=1.1$, $CHCl_3$). IR (film): 3400, 2240 cm^{-1}. ^1H NMR ($CDCl_3$): 3.18 (d, 2H, $J=13.5$ Hz, NCHHN), 3.96 (d, 2H, $J=13.5$ Hz, CHHN), 4.09 (d, 1H, $J=8.6$ Hz, CHN), 4.82 (d, 1H, $J=8.6$ Hz, CHOH), 7.20–7.60 (m, 15H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 54.6 (CH_2N), 62.0 (CHN), 64.4 (CHOH), 119.8 (CN), 127.2, 128.3, 128.4, 128.8, 129.1 ($CH_{arom.}$), 132.0 ($C_{arom.}$), 138.2 ($C_{arom.}$). MS (CI), m/z (%): 344 (M^++2, 15), 316 (100), 286 (19). Anal. calcd for $C_{23}H_{22}N_2O$: C, 80.67; H, 6.47; N, 8.18. Found: C: 80.47; H, 6.34; N, 8.15%.

2.13. (2*R*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-4-[(2-methoxyethoxy)methoxy]butanenitrile *syn*-2f

Colorless oil. $[\alpha]_D^{23}=+9.8$ ($c=1.2$, $CHCl_3$). IR (film): 3400, 2240 cm^{-1}. ^1H NMR ($CDCl_3$): 3.19 (m, 1H, CHN), 3.42 (s, 3H, CH_3O), 3.59 (m, 2H, OCH_2CH_2O), 3.61 (d, 2H, $J=13.5$ Hz, CHHPh), 3.75 (m, 2H, OCH_2CH_2O), 3.98 (m, 2H, CH_2O), 4.00 (d, 2H, $J=13.5$ Hz, CHHPh), 7.15–7.40 (m, 10H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 54.7 (NCH_2), 59.1 (CH_3), 59.7 (CH), 59.9 (CH), 63.1 (CH_2), 67.4 (CH_2), 71.7 (CH_2), 95.6 (OCH_2O), 119.6 (CN), 127.6, 128.6, 128.9 ($CH_{arom.}$), 138.2 ($C_{arom.}$). MS (CI), m/z (%): 386 (M^++2, 13), 358 (100), 328 (23), 282 (69), 252 (44). Anal. calcd for $C_{22}H_{28}N_2O_4$: C, 68.73; H, 7.34; N, 7.29. Found: C, 68.59; H, 7.22; N, 7.25%.

2.14. (2*S*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-4-[(2-methoxyethoxy)methoxy]butanenitrile *anti*-2f

Colorless oil. $[\alpha]_D^{23}=+24.2$ ($c=0.6$, $CHCl_3$). IR (film): 3380, 2260 cm^{-1}. ^1H NMR ($CDCl_3$): 3.23 (m, 1H, CHN), 3.39 (s, 3H, CH_3O), 3.57 (m, 2H, OCH_2CH_2O), 3.59 (d, 2H, $J=13.5$ Hz, CHHPh), 3.72 (m, 2H, OCH_2CH_2O), 3.97 (m, 2H, CH_2O), 4.03 (d, 2H, $J=13.5$ Hz, CHHPh), 4.58 (d, 1H, CHOH, $J=7.5$ Hz), 4.73 (s, 2H, OCH_2O), 7.25–7.40 (m, 10H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 55.0 (NCH_2), 58.9 (CH_3), 59.0 (CH), 59.8 (CH), 63.5 (CH_2), 67.3 (CH_2), 71.7 (CH_2), 95.7 (CH_2), 119.6 (CN), 127.6, 128.6, 129.1 ($CH_{arom.}$), 138.3 ($C_{arom.}$). MS (CI), m/z (%): 386 (M^++2, 12), 358 (100), 328 (21), 282 (69), 252 (58). Anal. calcd for $C_{22}H_{28}N_2O_4$: C, 68.73; H, 7.34; N, 7.29. Found: C, 68.61; H, 7.25; N, 7.21%.

2.15. Hydrolysis of the cyanohydrins 2: general method

A solution of cyanohydrin **2** (1 mmol) in dioxane–concentrated HCl (1:1, 10 mL) was heated under reflux for 12 h. The hydrolysate was washed with Et_2O and dried in vacuo. The residue was dissolved in water (10 mL), the solution adjusted to pH 5.5–6 with 2N NaOH and the mixture extracted with EtOAc (3×10 mL). The combined organic layers were washed with brine, dried over Na_2SO_4, concentrated and chromatographed (silica gel, hexane–ethyl acetate or $CHCl_3$–EtOH).

2.16. (2*R*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxybutanoic acid *syn*-3a

84% yield. Colorless oil. $[\alpha]_D^{23}=+66.0$ ($c=1.1$, $CHCl_3$). IR (film): 3600–2000 cm^{-1}. ^1H NMR ($CDCl_3$): 1.31 (d, 3H, $J=6.6$ Hz, CH_3), 3.28 (m, 1H, CHN), 3.62 (d, 2H, $J=13.4$ Hz, CHHPh), 4.05 (d, 1H; $J=4.8$ Hz, CHOH), 4.25 (d, 2H, $J=13.4$ Hz, CHHPh), 7.20–7.40 (m, 10H, $H_{arom.}$), 8.09 (br s, 2H, OH, COOH). ^{13}C NMR ($CDCl_3$): 8.9 (CH_3), 54.0 (NCH_2), 56.8 (CHN), 71.5

(CHOH), 128.1, 128.6, 129.3 ($CH_{arom.}$), 134.2 ($C_{arom.}$), 176.5 (CO_2H). MS (CI), *m/z* (%): 328 (M^++29, 14), 300 (M^++1, 100), 224 (15). Anal. calcd for $C_{18}H_{21}NO_3$: C, 77.22; H, 7.07; N, 4.68. Found: C, 77.44; H, 7.21; N, 4.61%.

2.17. (2*S*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxybutanoic acid *anti*-3a

78% yield. Colorless oil. $[\alpha]_D^{23}=+40.2$ ($c=1.0$, $CHCl_3$). IR (film): 3700–2000 cm^{-1}. ^1H NMR ($CDCl_3$): 1.38 (d, 3H, $J=6.7$ Hz, CH_3), 3.18 (dq, 1H, $J=9.8$ Hz, $J=6.7$ Hz, CHN), 3.66 (d, 2H, $J=13.2$ Hz, CHHPh), 3.99 (d, 1H, $J=9.8$ Hz, CHOH), 4.14 (d, 2H, $J=13.2$ Hz, CHHPh), 7.30–7.50 (m, 10H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 9.2 (CH_3), 53.3 (CH_2), 57.5 (CHN), 67.6 (CHOH), 129.0, 129.7 ($CH_{arom.}$), 131.4 ($C_{arom.}$), 175.7 (CO_2H). MS (CI), *m/z* (%): 328 (M^++29, 14), 300 (M^++1, 100), 224 (21). Anal. calcd for $C_{18}H_{21}NO_3$: C, 77.22; H, 7.07; N, 4.68. Found: C, 77.39; H, 6.96; N, 4.80%.

2.18. (2*R*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-5-methylhexanoic acid *syn*-3c

79% yield. Colorless oil. $[\alpha]_D^{23}=+60.3$ ($c=1.1$, $CHCl_3$). ^1H NMR ($CDCl_3$): 0.78 (d, 3H, $J=6.3$ Hz, CH_3), 0.95 (d, 3H, $J=6.3$ Hz, CH_3), 1.43 (m, 1H, CHHCHN), 1.72 (m, 1H, $(CH_3)_2CH$), 2.01 (m, 1H, CHHCHN), 3.24 (m, 1H, CHN), 3.61 (d, 2H, $J=13.3$ Hz, CHHN), 4.18 (d, 1H, $J=4.3$ Hz, CHOH), 4.38 (d, 2H, $J=13.3$ Hz, CHHN), 7.20–7.40 (m, 10H, $H_{arom.}$), 8.55 (br s, 2H, OH, CO_2H). ^{13}C NMR ($CDCl_3$): 21.6 (CH_3), 23.9 (CH_3), 24.5 (CH), 31.8 (CH_2), 54.7 (NCH_2), 58.3 (CHN), 69.7 (CHOH), 128.5, 128.8, 129.6 ($CH_{arom.}$), 134.2 ($C_{arom.}$), 177.1 (CO_2H). Anal. calcd for $C_{21}H_{27}NO_3$: C, 73.87; H, 7.97; N, 4.10. Found: C, 74.08; H, 7.78; N, 4.16%.

2.19. (2*S*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-5-methylhexanoic acid *anti*-3c

74% yield. Colorless oil. $[\alpha]_D^{23}=+33.8$ ($c=0.9$, $CHCl_3$). ^1H NMR ($CDCl_3$): 0.91 (d, 3H, $J=6.6$ Hz, CH_3), 0.92 (d, 3H, $J=6.6$ Hz, CH_3), 1.70 (m, 2H, CH_2CHN), 2.15 (m, 1H, $CH(CH_3)_2$), 3.17 (m, 1H, CHN), 3.76 (d, 2H, $J=13.4$ Hz, CHHPh), 4.10 (d, 2H, $J=13.4$ Hz, CHHPh), 4.15 (d, 1H, $J=8.9$ Hz, CHOH), 7.25–7.40 (m, 10H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 22.3 (CH_3), 23.3 (CH_3), 25.3 (CH), 36.2 (CH_2), 53.8 (CH_2N), 59.0 (CHN), 68.7 (CHOH), 128.8, 129.0, 129.8 ($CH_{arom.}$), 132.8 ($C_{arom.}$), 176.2 (CO_2H). Anal. calcd for $C_{21}H_{27}NO_3$: C, 73.87; H, 7.97; N, 4.10. Found: C, 73.60; H, 7.85; N, 3.95%.

2.20. (2*R*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-4-phenylbutanoic acid *syn*-3d

76% yield. Colorless solid. Mp 86–87°C (from hexane–ethyl acetate). $[\alpha]_D^{23}=+33.4$ ($c=1.0$, $CHCl_3$). IR (Nujol): 3600–3150, 750, 690 cm^{-1}. ^1H NMR ($CDCl_3$): 3.02 (dd, 1H, $J=12.7$ Hz, $J=4.2$ Hz, PhCHH), 3.20 (dd, 1H, $J=12.7$ Hz, $J=10.4$ Hz, PhCHH), 3.33 (m, 1H, CHN), 3.65 (d, 2H, $J=13.5$ Hz, CHHN), 3.88 (d, 1H, $J=3.8$ Hz, CHOH), 4.43 (d, 2H, $J=13.5$ Hz, CHHN), 7.05–7.40 (m, 15H, $H_{arom.}$), 7.96 (br s, 2H, OH, COOH). ^{13}C NMR ($CDCl_3$): 29.1 (CH_2CH), 54.8 (CH_2N), 61.6 (CHN), 69.1 (CHOH), 126.2, 128.0, 128.2, 128.4, 129.1, 129.3 ($CH_{arom.}$), 134.5, 137.1 ($C_{arom.}$), 176.9 (CO_2H). MS (CI), *m/z* (%): 404 (M^++29, 18), 376 (M^++1, 100), 300 (53), 284 (18). Anal. calcd for $C_{24}H_{25}NO_3$: C, 76.77; H, 6.71; N, 3.73. Found: C, 76.79; H, 6.75; N, 3.68%.

2.21. (2*S*,3*S*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-4-phenylbutanoic acid *anti*-3d

80% yield. Colorless solid. Mp 59–60°C (from hexane–ethyl acetate). $[\alpha]_D^{23}=+49.9$ ($c=1.1$, $CHCl_3$). IR (Nujol): 3600–2500, 740, 700 cm^{-1}. ^1H NMR ($CDCl_3$): 3.08 (dd, 1H, $J=15.0$ Hz, $J=9.6$ Hz, PhCHH), 3.28 (dd, 1H, $J=15.0$ Hz, $J=3.3$ Hz, PhCHH), 3.50 (m, 1H, CHN), 3.71 (d, 2H, $J=13.5$ Hz, CHHN), 3.95 (d, 2H, $J=13.5$ Hz, CHHN), 4.25 (d, 1H, $J=7.7$ Hz, CHOH), 7.05–7.40 (m, 15H, $H_{arom.}$), 9.20 (br s, 2H, OH, CO_2H). ^{13}C NMR ($CDCl_3$): 31.9 (CH_2CHN), 54.3 (CH_2N), 62.9 (CHN), 67.4 (CHOH), 126.7, 128.2, 128.6, 129.4 ($CH_{arom.}$), 133.7, 138.3 ($C_{arom.}$), 176.2 (CO_2H). MS (CI), *m/z* (%): 404 (M^++29, 15), 376 (M^++1, 100), 300 (65), 284 (23). Anal. calcd for $C_{24}H_{25}NO_3$: C, 76.77; H, 6.71; N, 3.73. Found: C, 76.86; H, 6.69; N, 3.78%.

2.22. (2*S*,3*R*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-3-phenylpropanoic acid *ent-syn*-3e

71% yield. Colorless solid. Mp 254–255°C (from hexane–ethyl acetate). $[\alpha]_D^{23}=-83.0$ ($c=1.0$, $CHCl_3$). IR (Nujol): 2700–2400 cm^{-1}. ^1H NMR ($CDCl_3$): 3.33 (d, 2H, $J=13.5$ Hz, CHHN), 4.13 (d, 1H, $J=7.1$ Hz, CHN), 4.17 (d, 2H, $J=13.5$ Hz, CHHN), 4.57 (d, 1H, $J=7.1$ Hz, CHOH), 7.20–7.50 (m, 15H, $H_{arom.}$), 8.45 (br s, 2H, OH, CO_2H). ^{13}C NMR ($CDCl_3$): 54.3 (NCH_2), 65.4 (CH), 68.4 (CH), 128.2, 128.6, 128.9, 129.3, 130.2 ($CH_{arom.}$), 135.4 ($C_{arom.}$), 174.1 (CO_2H). MS (CI), *m/z* (%): 390 (M^++29, 15), 362 (M^++1, 100), 286 (27), 198 (41), 121 (77). Anal. calcd for $C_{23}H_{23}NO_3$: C, 76.43; H, 6.41; N, 3.87. Found: C, 76.28; H, 6.29; N, 3.83%.

2.23. (2*R*,3*R*)-3-(*N*,*N*-Dibenzylamino)-2-hydroxy-3-phenylpropanoic acid *ent-anti*-3e

68% yield. Colorless solid. Mp 183–184°C (from hexane–ethyl acetate). $[\alpha]_D^{23}=-77.0$ ($c=1.1$, $CHCl_3$). IR (film): 2700–2400 cm^{-1}. ^1H NMR ($CDCl_3$): 3.31 (d, 2H, $J=13.2$ Hz, CHHN), 4.19 (d, 1H, $J=10.8$ Hz, CHN), 4.20 (d, 2H, $J=13.2$ Hz, CHHN), 4.72 (d, 1H, $J=10.8$ Hz, CHOH), 7.25–7.60 (m, 15H, $H_{arom.}$). ^{13}C NMR ($CDCl_3$): 54.1 (CH_2N), 64.3 (CH), 65.4 (CH), 128.1, 128.8, 129.1, 129.4, 129.6, 130.4 ($CH_{arom.}$), 132.0 ($C_{arom.}$), 175.4 (CO_2H). MS (CI), *m/z* (%): 390 (M^++29, 13), 362 (M^++1, 100), 286 (25), 198 (52), 121 (95). Anal. calcd for $C_{23}H_{23}NO_3$: C, 76.43; H, 6.41; N, 3.87. Found: C, 76.09; H, 6.45; N, 3.88%.

2.24. General method for the hydrogenolysis of *N*,*N*-dibenzylamino acids 3

To a solution of the appropriate *N*,*N*-dibenzylamino acid **3** (1 mmol) in a 1:1 mixture MeOH–H_2O (10 mL) was added 20% $Pd(OH)_2$-C (50 mg) in one portion. The mixture was stirred under a hydrogen atmosphere and the reaction was monitored by TLC. After completion of the reaction, the catalyst was removed by filtration through Celite and washed with water. The solvent was concentrated under reduced pressure to afford the pure product, which was crystallized from ethanol–water where necessary.

2.25. (2*R*,3*S*)-3-Amino-2-hydroxybutanoic acid *syn*-4a

92% yield. Colorless solid. Mp 223–225°C (dec.) (from EtOH–H_2O). $[\alpha]_D^{23}=+21.6$ ($c=1.1$, H_2O) [Lit.[17] $[\alpha]_D^{23}=+22.2$ ($c=0.5$, H_2O)]. ^{1}H NMR (D_2O): 1.10 (d, 3H, $J=6.8$ Hz, C$\underline{H}_3$), 3.36 (dq, 1H, $J=4.9$ Hz, $J=6.8$ Hz, C$\underline{H}$N), 3.88 (d, 1H, $J=4.9$ Hz, C$\underline{H}$OH). ^{13}C NMR (D_2O): 15.5 (C$\underline{H}_3$), 50.8 (C$\underline{H}$N), 73.1 (C$\underline{H}$OH), 177.2 (C$\underline{O}_2$H). MS (CI), m/z (%): 120 (M^++1, 100), 102 (4).

2.26. (2*S*,3*S*)-3-Amino-2-hydroxybutanoic acid *anti*-4a

95% yield. Colorless solid. Mp 240–241°C (from EtOH–H_2O). $[\alpha]_D^{23}=-25.7$ ($c=1.1$, H_2O) [Lit.[17] $[\alpha]_D^{23}=-26.1$ ($c=1.1$, H_2O)]. ^{1}H NMR (D_2O): 0.99 (d, 3H, $J=6.8$ Hz, C$\underline{H}_3$), 3.55 (dq, 1H, $J=3.4$ Hz, $J=6.8$ Hz, C$\underline{H}$N), 4.14 (d, 1H, $J=3.4$ Hz, C$\underline{H}$OH). ^{13}C NMR (D_2O): 14.2 (C$\underline{H}_3$), 51.7 (C$\underline{H}$N), 73.1 (C$\underline{H}$OH), 177.8 (C$\underline{O}_2$H). MS (CI), m/z (%): 120 (M^++1, 100), 102 (6).

2.27. (2*R*,3*S*)-3-Amino-2-hydroxy-5-methylhexanoic acid *syn*-4c

92% yield. Colorless solid. Mp 222–224°C (from EtOH–H_2O). $[\alpha]_D^{23}=+28.7$ ($c=0.3$, AcOH) [Lit.[18] $[\alpha]_D^{23}=+28.4$ ($c=0.45$, AcOH)]. ^{1}H NMR ($CDCl_3$): 0.74 (d, 3H, $J=6.3$ Hz, C$\underline{H}_3$), 0.75 (d, 3H, $J=6.3$ Hz, C$\underline{H}_3$), 1.36 (m, 2H, C$\underline{H}_2$); 1.50 (m, 1H, C$\underline{H}$(CH_3)$_2$), 3.37 (m, 1H, C$\underline{H}$N), 3.96 (d, 1H, $J=3.7$ Hz, C$\underline{H}$OH). ^{13}C NMR ($CDCl_3$): 23.3 (C$\underline{H}_3$), 23.8 (C$\underline{H}_3$), 25.8 (C$\underline{H}$(CH_3)$_2$), 40.0 (C$\underline{H}_2$), 54.1 (C$\underline{H}$N), 72.8 (C$\underline{H}$OH), 178.8 (C$\underline{O}_2$H).

2.28. (2*S*,3*S*)-3-Amino-2-hydroxy-5-methylhexanoic acid *anti*-4c

96% yield. Colorless solid. Mp 240–242°C (from EtOH–H_2O) [Lit.[19] mp 225–230°C]. $[\alpha]_D^{23}=-16.0$ ($c=0.4$, AcOH). ^{1}H NMR (D_2O): 0.68 (d, 3H, $J=6.4$ Hz, C$\underline{H}_3$), 0.73 (d, 3H, $J=6.4$ Hz, C$\underline{H}_3$), 1.12 (m, 1H, C$\underline{H}$HCH), 1.40 (m, 2H, CH$\underline{H}$CH and C$\underline{H}$(CH_3)$_2$), 3.44 (m, 1H, C$\underline{H}$N), 4.02 (d, 1H, $J=3.2$ Hz, C$\underline{H}$OH). ^{13}C NMR (D_2O): 23.0 (C$\underline{H}_3$), 24.8 (C$\underline{H}_3$), 25.9 (C$\underline{H}$(CH_3)$_2$), 38.3 (C$\underline{H}_2$), 54.4 (C$\underline{H}$N), 74.3 (C$\underline{H}$OH), 179.0 (C$\underline{O}_2$H).

2.29. (2*R*,3*S*)-3-Amino-2-hydroxy-4-phenylbutanoic acid *syn*-4d

95% yield. Colorless solid. Mp 209–210°C (from EtOH–H_2O). $[\alpha]_D^{23}=-27.0$ ($c=1.1$, 1N HCl) [Lit.[7a] $[\alpha]_D^{23}=-31.0$ (1N HCl)]. ^{1}H NMR (D_2O): 2.76 (dd, 1H, $J=8.4$ Hz, $J=14.1$ Hz, PhC$\underline{H}$H), 2.95 (dd, 1H, $J=6.8$ Hz, $J=14.1$ Hz, PhCH$\underline{H}$), 3.64 (ddd, 1H, $J=3.4$ Hz, $J=6.8$ Hz, $J=8.4$ Hz, C$\underline{H}$N), 3.93 (d, 1H, $J=3.4$ Hz, C$\underline{H}$OH), 7.14–7.26 (m, 5H, $\underline{H}_{arom.}$). ^{13}C NMR (D_2O): 37.7 (C$\underline{H}_2$), 57.5 (C$\underline{H}$N), 72.3 (C$\underline{H}$OH), 130.0, 131.6, 131.8 (C$\underline{H}_{arom.}$), 137.7 (C$\underline{}_{arom.}$), 178.6 (C$\underline{O}_2$H). MS (CI), m/z (%): 196 (M^++1, 100), 120 (30), 104 (19).

2.30. (2*S*,3*S*)-3-Amino-2-hydroxy-4-phenylbutanoic acid *anti*-4d

89% yield. Colorless solid. Mp 134–135°C (from EtOH–H_2O). $[\alpha]_D^{23}=-5.1$ ($c=0.9$, 1N HCl) [Lit.[20] $[\alpha]_D^{23}=-5.4$ ($c=0.5$, 1N HCl)]. ^{1}H NMR (D_2O): 2.72 (dd, 1H, $J=9.5$ Hz, $J=14.4$ Hz, PhC$\underline{H}$H), 2.81 (dd, 1H, $J=6.5$ Hz, $J=14.4$ Hz, PhCH$\underline{H}$), 3.79 (ddd, 1H, $J=3.0$ Hz, $J=6.5$ Hz, $J=9.5$ Hz, C$\underline{H}$N), 4.31 (d, 1H, $J=3.0$ Hz, C$\underline{H}$OH), 7.10–7.30 (m, 5H, $\underline{H}_{arom.}$). ^{13}C NMR (D_2O): 34.0 (C$\underline{H}_2$), 55.9 (C$\underline{H}$N), 70.7 (C$\underline{H}$OH), 128.8, 130.1, 130.6 (C$\underline{H}_{arom.}$), 135.9 (C$\underline{}_{arom.}$), 175.1 (C$\underline{O}_2$H). MS (CI), m/z (%): 196 (M^++1, 45), 120 (100), 107 (34).

2.31. (2*S*,3*R*)-3-Amino-2-hydroxy-3-phenylpropanoic acid *ent-syn*-4e

90% yield. Colorless solid. Mp 255–256°C (dec.) (from EtOH–H_2O). $[\alpha]_D^{23}=+14.4$ ($c=0.5$, 6N HCl) [Lit.[21] $[\alpha]_D^{23}=+14.9$ ($c=0.7$, 6N HCl)]. ^{1}H NMR (D_2O): 4.08 (d, 1H, $J=6.2$ Hz, C$\underline{H}$N), 4.30 (d, 1H, $J=6.2$ Hz, C$\underline{H}$OH), 7.15–7.30 (m, 5H, $\underline{H}_{arom.}$). ^{13}C NMR (D_2O): 59.9 (C$\underline{H}$N), 75.8 (C$\underline{H}$OH), 129.7, 131.5, 131.8 (C$\underline{H}_{arom.}$), 135.9 (C$\underline{}_{arom.}$), 178.8 (C$\underline{O}_2$H). MS (CI), m/z (%): 182 (M^++1, 100), 165 (29), 119 (60), 106 (85).

2.32. (2*R*,3*R*)-3-Amino-2-hydroxy-3-phenylpropanoic acid *ent-anti*-4e

96% yield. Colorless solid. Mp 109–110°C (from EtOH–H_2O). $[\alpha]_D^{23}=+3.6$ ($c=0.5$, 6N HCl). ^{1}H NMR (D_2O): 4.72 (d, 1H, $J=4.2$ Hz, C$\underline{H}$N), 4.77 (d, 1H, $J=4.1$ Hz, C$\underline{H}$OH), 7.35–7.45 (m, 5H, $\underline{H}_{arom.}$). ^{13}C NMR (D_2O): 57.9 (C$\underline{H}$N), 73.0 (C$\underline{H}$OH), 129.0, 130.0, 130.6 (C$\underline{H}_{arom.}$), 133.4 (C$\underline{}_{arom.}$), 176.7 (C$\underline{O}_2$H). MS (CI), m/z (%): 182 (M^++1, 100), 165 (22), 119 (25), 106 (68). Anal. calcd for $C_9H_{11}NO_3$: C, 59.66; H, 6.12; N, 7.73. Found: C, 59.87; H, 6.00; N, 7.55%.

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