Supporting Information

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Isomeric Control of Protein Recognition with Amino Acid- and 
Dipeptide-Functionalized Gold Nanoparticles

Chang-Cheng You, Sarit S. Agasti, Vincent M. Rotello

[a] Department of Chemistry, University of Massachusetts, 710 North Pleasant Street, Amherst, MA 01003
Email: rotello@chem.umass.edu
Section I. Synthesis and Characterization of Thiol Ligands

General synthetic procedure of Boc-protected dipeptides

Boc-protected amino acid (5.0 mmol) and amino acid ester (5.0 mmol) were suspended in dry
dichloromethane (40 mL) that placed in ice-bath. After 10 min, dicyclohexylcarbodiimide (6.0
mmol) and sodium bicarbonate (5.0 mmol) was added and the resultant mixture was stirred at
room temperature for 24 h. After removal of the precipitate, the filtrate was concentrated and
charged on SiO$_2$ column for purification. The yields were typically 50 ~ 70%.

Boc-L-Leu-L-Leu-OMe
$^1$H NMR (CDCl$_3$, TMS): $\delta$ 6.42 (br s, 1H, −NH−), 4.85 (br s, 1H, −CH<), 4.61 (m, 1H, −CH<),
4.09 (br s, 1H, −NH−), 3.73 (s, 3H, −OCH$_3$), 1.65 (m, 6H, −CH$_2$− + −CH<), 1.44 (s, 9H,
−C(CH$_3$)$_3$), 0.93 (dd, 12H, −CH$_3$).

Boc-L-Leu-D-Leu-OMe
$^1$H NMR (CDCl$_3$, TMS): $\delta$ 6.58 (br d, 1H, −NH−), 4.84 (br s, 1H, −CH<), 4.60 (m, 1H, −CH<),
4.13 (br s, 1H, −NH−), 3.72 (s, 3H, −OCH$_3$), 1.65 (m, 6H, −CH$_2$− + −CH<), 1.45 (s, 9H,
−C(CH$_3$)$_3$), 0.93 (dd, 12H, −CH$_3$).

Boc-L-Leu-Phe-OEt
$^1$H NMR (CDCl$_3$, TMS): $\delta$ 7.28 (m, 3H, Ar−H), 7.12 (m, 2H, Ar−H), 6.47 (br d, 1H, −NH−), 4.81
(m, 2H, −CH<), 4.15 (q, $^1$J = 7.1 Hz, 2H, −OCH$_2$−), 4.07 (br s, 1H, −NH−), 3.12 (m, 2H, ArCH$_2$−),
1.64 (m, 2H, −CH$_2$−), 1.44 (s+m, 10 H, −C(CH$_3$)$_3$ + −CH<), 1.23 (t, $^1$J = 7.1 Hz, 3H, −CH$_3$), 0.91
(q, 6H, −CH$_3$).

Boc-L-Leu-D-Phe-OMe
$^1$H NMR (CDCl$_3$, TMS): $\delta$ 7.28 (m, 3H, Ar−H), 7.11 (m, 2H, Ar−H), 6.55 (br d, 1H, −NH−), 4.86
(m, 1H, −CH<), 4.77 (m, 1H, −CH<), 4.10 (br s, 1H, −NH−), 3.71 (s, 3H, −OCH$_3$), 3.11 (m, 2H,
ArCH$_2$−), 1.62 (m, 2H, −CH$_2$−), 1.43 (s + m, 10H, −C(CH$_3$)$_3$ + −CH<), 0.89 (d, 6H, −CH$_3$).

Boc-L-Phe-D-Phe-OMe
$^1$H NMR (CDCl$_3$, TMS): $\delta$ 7.24 (m, 8H, Ar−H), 6.93 (m, 2H, Ar−H), 6.33 (br d, 1H, −NH−), 4.91
(m, 1H, −CH<), 4.83 (m, 1H, −CH<), 4.36 (br s, 1H, −NH−), 3.67 (s, 3H, −OCH$_3$), 3.05 (m, 4H,
Boc-d-Phe-L-Phe-OEt

$^1$H NMR (CDCl$_3$, TMS): $\delta$ 7.22 (m, 8H, Ar−H), 6.95 (m, 2H, Ar−H), 6.39 (br d, 1H, −NH−), 4.97 (m, 1H, −CH<), 4.80 (m, 1H, −CH<), 4.37 (br s, 1H, −NH−), 4.11 (m, 2H, −OCH$_2$−), 3.03 (m, 4H, ArCH$_2$−), 1.38 (s, 9H, −C(CH$_3$)$_3$), 1.19 (t, $^1J$ = 7.1 Hz, 3H, −CH$_3$).

Boc-D-Phe-D-Phe-OMe

$^1$H NMR (CDCl$_3$, TMS): $\delta$ 7.24 (m, 8H, Ar−H), 6.97 (m, 2H, Ar−H), 6.25 (br d, 1H, −NH−), 4.92 (m, 1H, −CH<), 4.78 (m, 1H, −CH<), 4.32 (br d, 1H, −NH−), 3.67 (s, 3H, −OCH$_3$), 3.04 (m, 4H, ArCH$_2$−), 1.40 (s, 9H, −C(CH$_3$)$_3$).

**General synthetic procedure of dipeptide esters**

Boc-protected dipeptide esters and trifluoroacetic acid were dissolved in dichloromethane. The reaction mixture was stirred at room temperature for 2 h. Then, the solvent was removed under a reduced pressure. The crude product was treated with aqueous sodium bicarbonate and extracted with dichloromethane. After drying over anhydrous sodium sulfate and removal of the solvent, dipeptide esters with free amine end were obtained in > 90% yield.

**L-Leu-L-Leu-OMe**

$^1$H NMR (CDCl$_3$, TMS): $\delta$ 7.64 (br d, 1H, −NH−), 4.60 (m, 1H, −CH<), 3.73 (s, 3H, −OCH$_3$), 3.42 (m, 1H, −CH<), 1.65 (m, 6H, −CH$_2$− + −CH<), 0.94 (m, 12H, −CH$_3$).

**L-Leu-D-Leu-OMe**

$^1$H NMR (CDCl$_3$, TMS): $\delta$ 7.66 (br d, 1H, −NH−), 4.59 (m, 1H, −CH<), 3.73 (s, 3H, −OCH$_3$), 3.44 (m, 1H, −CH<), 1.66 (m, 6H, −CH$_2$− + −CH<), 0.94 (m, 12H, −CH$_3$).

**L-Leu-L-Phe-OEt**

$^1$H NMR (CDCl$_3$, TMS): $\delta$ 7.68 (br d, 1H, −NH−), 7.27 (m, 3H, Ar−H), 7.13 (m, 2H, Ar−H), 4.84 (q, 1H, −CH<), 4.17 (q, $^1J$ = 7.1 Hz, 2H, −OCH$_2$−), 3.36 (dd, 1H, −CH<), 3.12 (m, 2H, ArCH$_2$−), 1.61 (m, 2H, −CH$_2$−), 1.38 (m, 3H, −CH< + −NH$_2$), 1.24 (t, $^1J$ = 7.1 Hz, 3H, −CH$_3$), 0.91 (dd, 6H, −CH$_3$).

**L-Leu-D-Phe-OMe**
\[ ^1\text{H NMR (CDCl}_3, \text{TMS)}: \delta 7.60 \text{ (br d, 1H, }-\text{NH})\), 7.27 \text{ (m, 3H, Ar} -\text{H})\), 7.14 \text{ (m, 2H, Ar} -\text{H})\), 4.84 \text{ (m, 1H, }-\text{CH})\), 3.72 \text{ (s, 3H, }-\text{OCH}_3\), 3.33 \text{ (dd, 1H, }-\text{CH})\), 3.13 \text{ (m, 2H, ArCH} -\text{H})\), 1.66 \text{ (m, 2H, }-\text{CH}_2\), 1.33 \text{ (m, 3H, }-\text{CH}) + -\text{NH})\), 0.92 \text{ (dd, 6H, }-\text{CH}_3\).

**L-Phe-d-Phe-OMe**

\[ ^1\text{H NMR (CDCl}_3, \text{TMS)}: \delta 7.66 \text{ (br d, 1H, }-\text{NH})\), 7.25 \text{ (m, 8H, Ar} -\text{H})\), 7.09 \text{ (m, 2H, Ar} -\text{H})\), 4.86 \text{ (m, 1H, }-\text{CH})\), 3.72 \text{ (s, 3H, }-\text{OCH}_3\), 3.55 \text{ (dd, 1H, }-\text{CH})\), 3.25 \text{ (dd, 1H, ArCH} -\text{H})\), 3.11 \text{ (m, 2H, ArCH} -\text{H})\), 2.64 \text{ (dd, 1H, ArCH} -\text{H})\), 1.44 \text{ (br s, 2H, }-\text{NH}_2\).

**D-Phe-l-Phe-OEt**

\[ ^1\text{H NMR (CDCl}_3, \text{TMS)}: \delta 7.65 \text{ (br d, 1H, }-\text{NH})\), 7.28 \text{ (m, 8H, Ar} -\text{H})\), 7.11 \text{ (m, 2H, Ar} -\text{H})\), 4.84 \text{ (m, 1H, }-\text{CH})\), 4.17 \text{ (q, }^1J = 7.1 \text{ Hz, 2H, }-\text{OCH}_2\), 3.55 \text{ (dd, 1H, }-\text{CH})\), 3.27 \text{ (dd, 1H, ArCH} -\text{H})\), 3.11 \text{ (m, 2H, ArCH} -\text{H})\), 2.63 \text{ (dd, 1H, ArCH} -\text{H})\), 1.61 \text{ (br s, 2H, }-\text{NH}_2\), 1.23 \text{ (t, }^1J = 7.1 \text{ Hz, 3H, }-\text{CH}_3\).

**D-Phe-d-Phe-OMe**

\[ ^1\text{H NMR (CDCl}_3, \text{TMS)}: \delta 7.74 \text{ (br d, 1H, }-\text{NH})\), 7.27 \text{ (m, 8H, Ar} -\text{H})\), 7.94 \text{ (m, 2H, Ar} -\text{H})\), 4.89 \text{ (m, 1H, }-\text{CH})\), 3.71 \text{ (s, 3H, }-\text{OCH}_3\), 3.60 \text{ (dd, 1H, }-\text{CH})\), 3.11 \text{ (m, 3H, ArCH} -\text{H})\), 2.59 \text{ (dd, 1H, ArCH} -\text{H})\), 1.70 \text{ (br s, 2H, }-\text{NH}_2\).

**General synthetic procedure of trityl-protected thiol ligands**

Trityl-protected thioacid \((\text{H}_3\text{CS(CH}_2)_3\text{TEG-CH}_2\text{COOH, 1.0 mmol})\) was dissolved in dry dichloromethane (20 mL) that was placed in an ice-bath. When the temperature reached about 0 °C, corresponding amino acid ester or dipeptide ester (1.0 mmol) and dicyclohexylcarbodiimide (1.5 mmol) were added successively. The mixture was stirred at room temperature for 36 h. The insoluble stuff was removed by suction filtration. The filtrate was concentrated and charged on SiO\(_2\) column for purification. The yields were around 70%.

**Ph\(_3\text{CS(CH}_2)_3\text{TEG-d-Leu-OMe**}

\[ ^1\text{H NMR (CDCl}_3, \text{TMS)}: \delta 7.40 \text{ (m, 6H, Ar} −\text{H})\), 7.27 \text{ (m, 7H, Ar} −\text{H} + −\text{NH}−\), 7.20 \text{ (m, 3H, Ar} −\text{H})\), 4.67 \text{ (m, 1H, }-\text{CH})\), 4.02 \text{ (q, 2H, }-\text{OCH}_2\), 3.73 \text{ (s, 3H, }-\text{OCH}_3\), 3.66 \text{ (m, 14H, }-\text{CH}_2\), 3.57 \text{ (m, 2H, }-\text{CH}_2\), 3.44 \text{ (t, 2H, }-\text{OCH}_2\), 2.13 \text{ (t, 2H, }-\text{SCH}_2\), 1.67 \text{ (m, 2H, }-\text{CH}_2\), 1.56 \text{ (m, 3H, }-\text{CH}_3\).
Ph₃CS(CH₂)₄-TEG-d-Phe-OMe

¹H NMR (CDCl₃, TMS): δ 7.41 (m, 6H, Ar−H), 7.28 (m, 9H, Ar−H), 7.20 (m, 6H, Ar−H + −NH−), 4.90 (m, 1H, −CH<), 3.97 (q, 2H, −OCH₂−), 3.71 (s, 3H, −OCH₃), 3.63 (m, 16H, −OCH₂−), 3.43 (t, 2H, −OCH₂−), 3.13 (m, 2H, −CH₂Ar), 2.13 (t, 2H, −SCH₂−), 1.56 (m, 2H, −CH₂−), 1.38 (m, 2H, −CH₂−), 1.23 (m, 14H, −CH₂−).

Ph₃CS(CH₂)₄-TEG-Gly-Gly-OBu¹

¹H NMR (CDCl₃, TMS): δ 7.75 (br s, 1H, −NH−), 7.41 (m, 6H, Ar−H), 7.20 (m, 3H, Ar−H), 6.71 (br s, 1H, −NH−), 4.07 (s, 2H, −OCH₂−), 4.03 (d, 2H, −CH₂CO−), 3.92 (d, 2H, −CH₂CO−), 3.72 (m, 2H, −OCH₂−), 3.64 (m, 12H, −OCH₂−), 3.57 (m, 2H, −OCH₂−), 3.43 (m, 2H, −OCH₂−), 2.13 (t, 2H, −SCH₂−), 1.54 (m, 2H, −CH₂−), 1.46 (s, 9H, −C(CH₃)₃), 1.38 (m, 2H, −CH₂−), 1.23 (m, 14H, −CH₂−).

Ph₃CS(CH₂)₄-TEG-l-Leu-l-Leu-OMe

¹H NMR (CDCl₃, TMS): δ 7.41 (m, 7H, Ar−H + −NH−), 7.28 (m, 6H, Ar−H), 7.20 (m, 3H, Ar−H), 6.54 (d, 1H, −NH−), 4.56 (m, 1H, −CH<), 4.49 (m, 1H, −CH<), 4.01 (q, 2H, −OCH₂−), 3.8~3.5 (m, 19H, −OCH₂− + −OCH₃), 3.43 (t, 2H, −OCH₂−), 2.13 (t, 2H, −SCH₂−), 1.8~1.7 (m, 8H, −CH₂− + −CH<), 1.38 (m, 2H, −CH₂−), 1.26 (m, 14H, −CH₂−), 0.94 (m, 12H, −CH₃).

Ph₃CS(CH₂)₄-TEG-l-Leu-d-Leu-OMe

¹H NMR (CDCl₃, TMS): δ 7.41 (m, 7H, Ar−H + −NH−), 7.27 (m, 6H, Ar−H), 7.21 (m, 3H, Ar−H), 6.72 (d, 1H, −NH−), 4.56 (m, 1H, −CH<), 4.49 (m, 1H, −CH<), 4.04 (q, 2H, −OCH₂−), 3.8~3.5 (m, 19H, −OCH₂− + −OCH₃), 3.43 (t, 2H, −OCH₂−), 2.13 (t, 2H, −SCH₂−), 1.8~1.7 (m, 8H, −CH₂− + −CH<), 1.4~1.11 (m, 16H, −CH₂−), 0.94 (m, 12H, −CH₃).

Ph₃CS(CH₂)₄-TEG-l-Leu-l-Phe-OEt

¹H NMR (CDCl₃, TMS): δ 7.41 (m, 6H, Ar−H), 7.27 (m, 9H, Ar−H), 7.20 (m, 3H, Ar−H), 7.13 (m, 3H, Ar−H + −NH−), 6.61 (br d, 1H, −NH−), 4.78 (m, 1H, −CH<), 4.44 (m, 1H, −CH<), 4.15 (q, 2H, −CO₂CH₂−), 3.96 (q, 2H, −OCH₂−), 3.64 (m, 14H, −OCH₂−), 3.56 (m, 2H, −OCH₂−), 3.43 (t, 2H, −OCH₂−), 3.10 (m, 2H, −CH₂Ar), 2.13 (t, 2H, −SCH₂−), 1.56 (m, 5H, −CH₂− + −CH<), 1.38
(m, 2H, −CH2−), 1.22 (m, 17H, −CH2− + −CH3), 0.91 (dd, 6H, −CH3).

**Ph₃CS(CH₂)₁₁-TEG-L-Leu-d-Phe-OMe**

1H NMR (CDCl₃, TMS): δ 7.41 (m, 6H, Ar−H), 7.27 (m, 9H, Ar−H), 7.20 (m, 3H, Ar−H), 7.15 (d, 1H, −NH−), 7.10 (m, 2H, Ar−H), 6.60 (br d, 1H, −NH−), 4.82 (m, 1H, −CH<), 4.45 (m, 1H, −CH<), 3.98 (q, 2H, −OCH₂−), 3.71 (s, 3H, −OCH₃), 3.64 (m, 16H, −OCH₂−), 3.43 (t, 2H, −OCH₂−), 3.10 (m, 2H, −OCH₂−), 2.13 (t, 2H, −SCH₂−), 1.56 (m, 5H, −CH₂− + −CH<), 1.38 (m, 2H, −CH₂−), 1.26 (m, 14H, −CH₂−), 0.89 (dd, 6H, −CH₃).

**Ph₃CS(CH₂)₁₁-TEG-L-Phe-d-Phe-OMe**

1H NMR (CDCl₃, TMS): δ 7.41 (m, 6H, Ar−H), 7.27 (m, 11H, Ar−H), 7.20 (m, 7H, Ar−H + −NH−), 6.90 (m, 2H, Ar−H), 6.46 (br d, 1H, −NH−), 4.80 (m, 1H, −CH<), 4.66 (m, 1H, −CH<), 3.92 (q, 2H, −OCH₂−), 3.7 ~ 3.5 (m, 19H, −OCH₂− + −OCH₃), 3.42 (t, 2H, −OCH₂−), 3.2 ~ 2.9 (m, 4H, −CH₂Ar), 2.13 (t, 2H, −SCH₂−), 1.55 (m, 2H, −CH₂−), 1.38 (m, 2H, −CH₂−), 1.22 (m, 14H, −CH₂−).

**Ph₃CS(CH₂)₁₁-TEG-d-Phe-L-Phe-OEt**

1H NMR (CDCl₃, TMS): δ 7.41 (m, 6H, Ar−H), 7.27 (m, 11H, Ar−H), 7.21 (m, 7H, Ar−H + −NH−), 6.90 (m, 2H, Ar−H), 6.45 (br d, 1H, −NH−), 4.77 (m, 1H, −CH<), 4.66 (m, 1H, −CH<), 4.12 (m, 2H, −CO₂CH₂−), 3.92 (q, 2H, −OCH₂−), 3.64 (m, 16H, −OCH₂−), 3.42 (t, 2H, −OCH₂−), 3.2 ~ 2.9 (m, 4H, −CH₂Ar), 2.13 (t, 2H, −SCH₂−), 1.55 (m, 2H, −CH₂−), 1.38 (m, 2H, −CH₂−), 1.24 (m, 17H, −CH₂− + −CH₃).

**Ph₃CS(CH₂)₁₁-TEG-d-Phe-d-Phe-OMe**

1H NMR (CDCl₃, TMS): δ 7.41 (m, 6H, Ar−H), 7.25 (m, 18H, Ar−H + −NH−), 7.02 (m, 2H, Ar−H), 6.44 (br d, 1H, −NH−), 4.75 (m, 1H, −CH<), 4.65 (m, 1H, −CH<), 3.91 (q, 2H, −OCH₂−), 3.67 (s, 3H, −OCH₃), 3.64 (m, 16H, −OCH₂−), 3.42 (t, 2H, −OCH₂−), 3.06 (m, 4H, −CH₂Ar), 2.13 (t, 2H, −SCH₂−), 1.56 (m, 2H, −CH₂−), 1.24 (m, 16H, −CH₂−).

**General synthetic procedure of thiol ligands bearing dipeptide functionality**

Trityl protected thioligands obtained above were dissolved in tetrahydrofuran (20 mL). Subsequently, aqueous lithium hydroxide (1 M, 10 equivalent) was added and the solution was
stirred at room temperature for 2 h. The solution was acidified with 1 M HCl to pH ca. 2 and
diluted with 200 mL water and extracted with ethyl acetate (50 mL × 5). The organic layers were
combined and washed successively with water and brine and dried over anhydrous sodium sulfate.
After removal of the solvent and drying under high vacuum, the residue was dissolved in dry
dichloromethane and stoichiometric trifluoroacetic acid (TFA) was added under stirring. The
color of the solution was immediately turned to yellow. Subsequently, trisopropylsilane (TIPS,
1.2 equivalent) was added. The color of the solution recovered slowly to colorless. The
reaction was allowed to proceed at room temperature for 12 h. The solvent and excess TFA and
TIPS were removed under reduced pressure. The residue was charged on SiO₂ column for
purification. The yields were typically from 50% to 75%.

**HS(CH₂)₁₁-TEG-d-Leu-OH**

³¹H NMR (CDCl₃, TMS): δ 7.62 (d, 1H, –NH–), 4.61 (m, 1H, –CH<), 4.03 (q, 2H, –OCH₂–), 3.67
(m, 16H, –OCH₂–), 3.45 (t, 2H, –OCH₂–), 2.51 (q, 2H, –SCH₂–), 1.70 (m, 3H, –CH₂– + –CH<),
1.57 (m, 4H, –CH₂–), 1.26 (m, 14H, –CH₂–), 0.95 (m, 6H, –CH₃).

**HS(CH₂)₁₁-TEG-d-Phe-OH**

³¹H NMR (CDCl₃, TMS): δ 7.48 (d, 1H, –NH–), 7.24 (m, 5H, Ar–H), 4.93 (m, 1H, –CH<), 3.98 (q,
2H, –OCH₂–), 3.59 (m, 16H, –OCH₂–), 3.46 (t, 2H, –OCH₂–), 3.20 (m, 2H, –CH₂Ar), 2.52 (q, 2H,
–SCH₂–), 1.58 (m, 4H, –CH₂–), 1.27 (m, 14H, –CH₂–).

**HS(CH₂)₁₁-TEG-Gly-Gly-OH**

³¹H NMR (CDCl₃, TMS): δ 8.23 (br s, 1H, –NH–), 7.79 (br s, 1H, –NH–), 4.12 (s, 2H, –OCH₂–),
4.05 (s, 2H, –CH₃CO–), 3.99 (s, 2H, –CH₂O–), 3.67 (m, 16H, –OCH₂–), 3.44 (t, 2H, –OCH₂–),
2.52 (q, 2H, –SCH₂–), 1.58 (m, 4H, –CH₂–), 1.27 (m, 14H, –CH₂–).

**HS(CH₂)₁₁-TEG-L-Leu-L-Leu-OH**

³¹H NMR (CDCl₃, TMS): δ 7.46 (br s, 1H, –NH–), 6.84 (br s, 1H, –NH–), 4.50 (m, 2H, –CH<),
4.04 (s, 2H, –OCH₂–), 3.65 (m, 16H, –OCH₂–), 3.45 (t, 2H, –OCH₂–), 2.52 (q, 2H, –SCH₂–),
1.62 (m, 10H, –CH₂– + –CH<), 1.27 (m, 14H, –CH₂–), 0.94 (q, 12H, –CH₃).

**HS(CH₂)₁₁-TEG-L-Leu-D-Leu-OH**

-S7-
$^1$H NMR (CDCl$_3$, TMS): δ 7.58 (br s, 2H, −NH−), 4.54 (m, 2H, −CH<), 4.03 (s, 2H, −OCH$_2$−), 3.66 (m, 16H, −OCH$_2$−), 3.44 (t, 2H, −OCH$_2$−), 2.52 (q, 2H, −SCH$_2$−), 1.59 (m, 10H, −CH$_2$− + −CH<), 1.27 (m, 14H, −CH$_2$−), 0.92 (m, 12H, −CH$_3$).

**HS(CH$_2$)$_{11}$-TEG-l-Leu-l-Phe-OH**

$^1$H NMR (CDCl$_3$, TMS): δ 7.70 (br s, 1H, −NH−), 6.98 (m, 6H, Ar−H + −NH−), 4.77 (m, 1H, −CH<), 4.45 (m, 1H, −CH<), 4.05 (q, 2H, −OCH$_2$−), 3.65 (m, 16H, −OCH$_2$−), 3.46 (t, 2H, −OCH$_2$−), 3.13 (m, 2H, −CH$_2$Ar), 2.52 (q, 2H, −SCH$_2$−), 1.58 (m, 7H, −CH$_2$− + −CH<), 1.26 (m, 14H, −CH$_2$−), 0.87 (dd, 6H, −CH$_3$).

**HS(CH$_2$)$_{11}$-TEG-l-Leu-d-Phe-OH**

$^1$H NMR (CDCl$_3$, TMS): δ 7.42 (br d, 1H, −NH−), 7.28 (m, 3H, Ar−H), 7.18 (m, 2H, Ar−H), 6.82 (br s, 1H, −NH−), 4.78 (q, 2H, −CH<), 4.65 (m, 1H, −CH<), 3.98 (q, 2H, −OCH$_2$−), 3.64 (m, 16H, −OCH$_2$−), 3.46 (t, 2H, −OCH$_2$−), 3.13 (m, 2H, −CH$_2$Ar), 2.52 (q, 2H, −SCH$_2$−), 1.58 (m, 7H, −CH$_2$− + −CH<), 1.27 (m, 14H, −CH$_2$−), 0.88 (dd, 6H, −CH$_3$).

**HS(CH$_2$)$_{11}$-TEG-l-Phe-d-Phe-OH**

$^1$H NMR (CDCl$_3$, TMS): δ 7.52 (br d, 1H, −NH−), 7.22 (m, 8H, Ar−H), 7.02 (m, 2H, Ar−H), 6.72 (br d, 1H, −NH−), 4.78 (q, 2H, −CH<), 3.89 (q, 2H, −OCH$_2$−), 3.64 (m, 16H, −OCH$_2$−), 3.45 (t, 2H, −OCH$_2$−), 3.01 (m, 4H, −CH$_2$Ar), 2.52 (q, 2H, −SCH$_2$−), 1.58 (m, 4H, −CH$_2$−), 1.27 (m, 14H, −CH$_2$−).

**HS(CH$_2$)$_{11}$-TEG-d-Phe-l-Phe-OH**

$^1$H NMR (CDCl$_3$, TMS): δ 7.63 (br s, 1H, −NH−), 7.23 (m, 6H, Ar−H), 7.15 (m, 2H, Ar−H), 7.04 (m, 2H, Ar−H), 6.90 (br s, 1H, −NH−), 4.80 (m, 2H, −CH<), 3.87 (q, 2H, −OCH$_2$−), 3.63 (m, 16H, −OCH$_2$−), 3.45 (t, 2H, −OCH$_2$−), 3.03 (m, 4H, −CH$_2$Ar), 2.51 (q, 2H, −SCH$_2$−), 1.58 (m, 4H, −CH$_2$−), 1.26 (m, 14H, −CH$_2$−).

**HS(CH$_2$)$_{11}$-TEG-d-Phe-d-Phe-OH**

$^1$H NMR (CDCl$_3$, TMS): δ 7.61 (br d, 1H, −NH−), 7.21 (m, 8H, Ar−H), 7.05 (m, 2H, Ar−H), 6.62 (br s, 1H, −NH−), 4.70 (m, 2H, −CH<), 3.93 (q, 2H, −OCH$_2$−), 3.65 (m, 16H, −OCH$_2$−), 3.46 (t, 2H, −OCH$_2$−), 3.06 (m, 4H, −CH$_2$Ar), 2.51 (q, 2H, −SCH$_2$−), 1.58 (m, 4H, −CH$_2$−), 1.26 (m, 14H,
Section II. Construction of Functional Gold Nanoparticles and $^1$H NMR Spectra

General procedure for ligand exchange

Pentanethiol coated gold nanoparticles ($d = 2$ nm) were prepared according to the previously reported protocol. Place-exchange reactions were conducted to replace the 1-pentanethiol ligand on the nanoparticle surface with amino acid- or dipeptide-functionalized ligands. Typically, 20 mg of 1-pentanethiol coated gold nanoparticles were added to a solution of 60 mg thioligands in dichloromethane. The mixture were stirred at room temperature for 2~3 days. The ligand-exchanged nanoparticles precipitated from the solution automatically and were collected by centrifugation. The nanoparticles were washed thoroughly with dichloromethane and dried under high vacuum. The nanoparticles are soluble in water due to the presence of surface carboxylates. As compared with the ligand precursor, the $^1$H NMR signals of nanoparticles are significantly broadening (vide infra). No signals of free ligands are observed in all $^1$H NMR spectra.
Figure S1. 400 MHz $^1$H NMR spectrum of NP_D-Leu in D$_2$O.

Figure S2. 400 MHz $^1$H NMR spectrum of NP_D-Phe in D$_2$O.
Figure S3. 400 MHz $^1$H NMR spectrum of NP_Gly-Gly in D$_2$O.
**Figure S4.** 400 MHz $^1$H NMR spectrum of NP$_{L}$-Leu-L-Leu in D$_2$O.

**Figure S5.** 400 MHz $^1$H NMR spectrum of NP$_{L}$-Leu-D-Leu in D$_2$O.
Figure S6. 400 MHz $^1$H NMR spectrum of NP_L-Leu-L-Phe in D$_2$O.

Figure S7. 400 MHz $^1$H NMR spectrum of NP_L-Leu-D-Phe in D$_2$O.
Figure S8. 400 MHz $^1$H NMR spectrum of NP$_L$-Phe-D-Phe in D$_2$O.

Figure S9. 400 MHz $^1$H NMR spectrum of NP$_D$-Phe-L-Phe in D$_2$O.
Figure S10. 400 MHz $^1$H NMR spectrum of NP$_{D}$-Phe-D-Phe in D$_2$O