Supporting Information

for

Carbohydrate Functionalized Iron(III) complexes as Biomimetic Siderophores

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1. General Information

All chemicals used were reagent grade and used as supplied except where noted. Analytical thin layer chromatography (TLC) was performed on Merck silica gel 60 F254 plates (0.25 mm). Compounds were visualized by UV irradiation or dipping the plate in CAN solution followed by

heating. Column chromatography was carried out using force flow of the indicated solvent on Fluka Kieselgel 60 (230–400 mesh). ^{1}H and ^{13}C NMR spectra were recorded on Bruker 500 MHz (or 125 MHz for 13C) and Jeol 400 MHz (or 100 MHz for 13C) using residual solvents signals as an internal reference ($CDCl_3$ δH, 7.26 ppm, δc 77.3 ppm and CD_3OH δH 3.31 ppm, δc 49.0 ppm). The chemical shifts (δ) are reported in *ppm* and coupling constants (*J*) in Hz. IR spectra were recorded on a Perkin Elmer 1600 FTIR spectrometer. Optical rotation measurements were conducted using a Perkin- Elmer 241 polarimeter. 2,3-dihydroxy benzoic acid and 2,3,4,5,6-pentafluorophenol were purchased from Sigma-aldrich. ConcavalinA was purchased from Sigma-aldrich. Professor Orndorff (North Carolina State University) for providing ORN178 and 208 *E. coli* stains.

2. General Procedures:

General Procedure A: Synthesis of catechol substituted sugar-monomers or tripods or nanopodes.

The Boc-protected amino-sugar or tripods or nonapodes (1.0 equiv) was dissolved in dichloromethane/trifluoroacetic acid (3:1, 10 mL) and stirred at room temperature for 1 h. The solvent was evaporated *in vacuo* and the residue redissolved in anhydrous dichloromethane (20 mL). 2,3-*O*-benzyl-benzoic acid (1.5 equiv), *N,N'*-Diisopropylcarbodiimide (1.5 eq) and HOBT (0.1 eq) were added, the pH was adjusted to 8 with triethylamine and stirred at room temperature for 12 h. The solvent was evaporated *in vacuo* and purified by flash silica column chromatography.

General Procedure B: Deacetylation and hydrogenolysis of sugar derivatives.

To a solution of sugar-substituted tripod (1.0 equiv) in methanol (10 mL) was added sodium methoxide (6 to 20 eq) and stirred for 2 h at rt. The mixture was neutralized with amberlite–acidic resin, filtered and then concentrated *in vacuo*. The residue was dissolved once more in

methanol (10 mL), 10 % Pd/C (Pd/C, 10 mol % added) and hydrogen gas was bubbled through the solution for 12 h. The solution was filtered over celite and the filtrate concentrated *in vacuo* to afford the final compound.

General Procedure C: Synthesis of iron(III) complexes.

To a solution of dendron (**10-11, 19-20, 25-26)** (3.3 eq) in MeOH (10 mL) were added the appropriate metal salt (1 eq) and refluxed for 12 h. The solvent was evaporated to obtain black color oily residue, which was used as such for next step.[1]

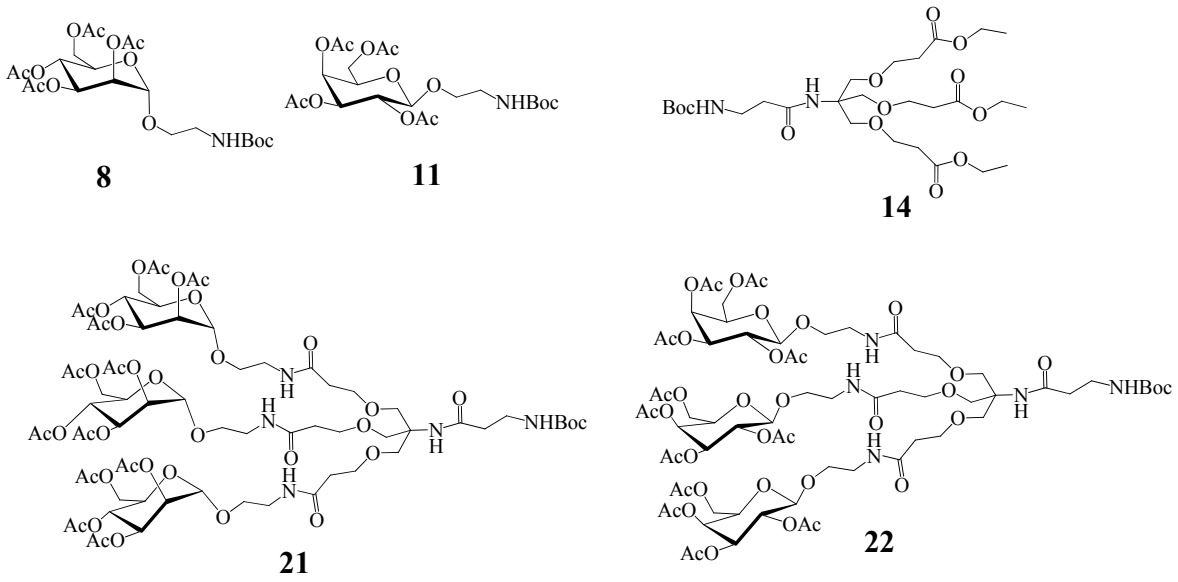
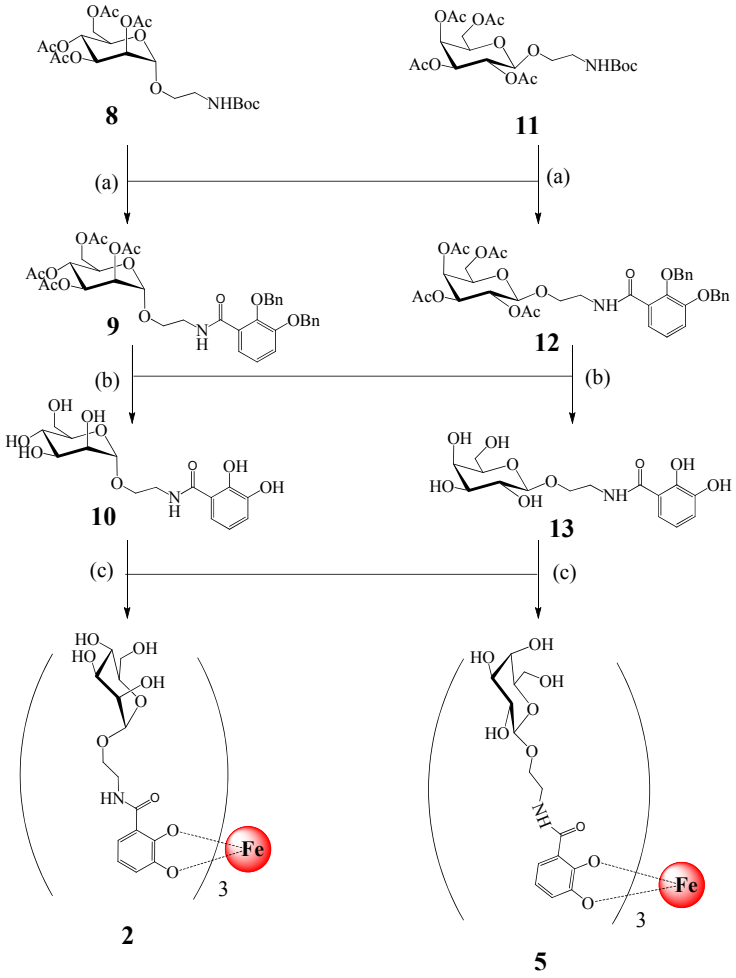


Figure 1. Peracetylated mannose and galactose tripode amine were synthesized using published procedures.[1]

3. Synthesis of ligand 10 and 13



Scheme 1. Reagents and Conditions: (a) TFA/DCM; 2,3-bis(benzyolxy)-benzoic acid, DIC/HOBT/DCM; (b) NaOMe/MeOH; H_2/Pd-C/MeOH. (c) $FeCl_3$/MeOH.

2,3-bis(benzyolxy)-*N*-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethylbenzamide 9 . General procedure A using 2-(*tert*-butoxycarbonylamino)ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside **8** (0.2 g, 0.4 mmol), 2,3-bis(benzyolxy)-benzoic acid (0.2 g, 0.5 mmol), DIC (94 µL, 0.5 mmol) and HOBT (10 mg, 0.06 mmol). Purification by flash chromatography petroleum ether : ethyl acetate (60:40) yielded 2,3-bis(benzyolxy)-*N*-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethylbenzamide (0.158 g, 56%). R_f = 0.5 (PE : EtOAc, 60:40); $[\alpha]_D^{r.t}$ = +33.1 (c = 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.11 (t, 1H, J = 4.0 Hz), 7.72-7.62 (m, 2H), 7.50-7.30 (m, 9H), 7.18-7.10 (m, 2H), 5.32- 5.06 (m, 8H), 4.72 (s, 1H), 4.22 (dd, 1H, J = 5.2,

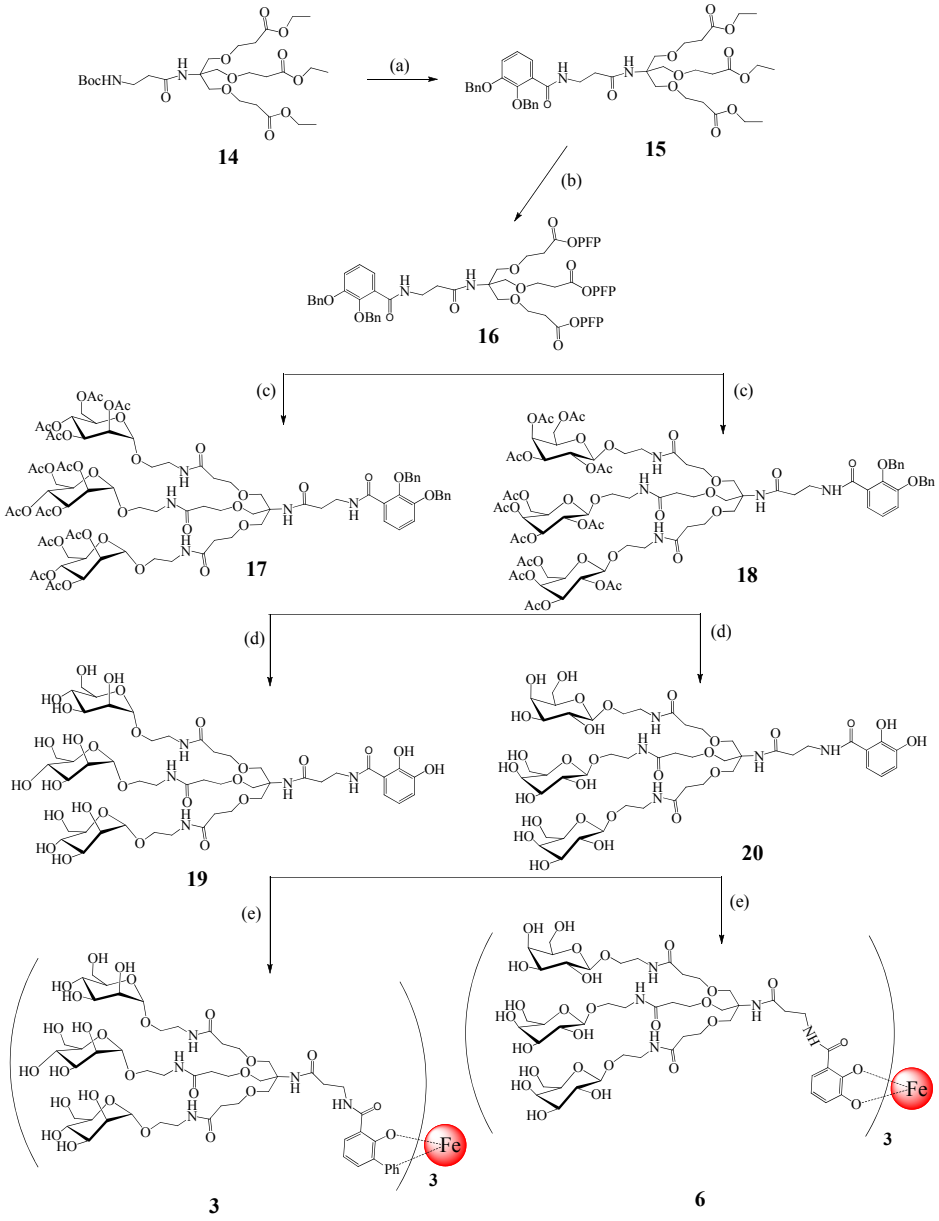
7.2 Hz); 4.00 (d, 1H, *J* = 10.5 Hz), 3.94-3.90 (m, 1H); 3.71-3.62 (m, 1H), 3.48-3.38 (m, 2H), 2.13 (s, 3H), 2.04 (s, 3H), 1.96 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.6, 169.9, 169.6, 165.4, 151.6, 146.7, 136.4, 132.1, 128.9, 128.3, 127.7 127.2, 124.4, 123.3, 117.3, 97.5, 71.8, 69.4, 69.1, 68.4, 66.8, 66.2, 62.4, 39.1, 20.7, 20.6 HRMS (MALDI-ToF) (*m/z*); calcd. for $C_{37}H_{41}NO_{13}Na$ 730.2476; found:730.2476 $[M+Na]^+$.

2,3-bis(benzyolxy)-*N*-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethylbenzamide. 12. General procedure A using 2-(*tert*-butoxycarbonylamino)ethoxy-2,3,4,6-tetra-*O*-acetyl- *β*-D-galactopyranoside **11** (0.2 g, 0.4 mmol), 2,3-bis(benzyolxy)-benzoic acid (0.2 g, 0.5 mmol) DIC (95 µL, 0.5 mmol) and HOBT (10 mg, 0.06 mmol). Purification by flash chromatography petroleum ether : ethylacetate (60:40) yielded 2,3-bis(benzyolxy)-*N*-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethylbenzamide (0.136 g, 48%). R_f = 0.5 (PE : EtOAc, 60:40); $[\alpha]_D^{r.t}$ = +14.1 (c = 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): 8.14 (t, 1H, *J* = 4.0 Hz), 7.72-7.62 (m, 2H), 7.50-7.30 (m, 9H), 7.18-7.10 (m, 2H), 5.3 (d, 1H, J = 2.8 Hz), 5.31-5.06 (m, 4H), 4.99-4.93 (m, 2H), 4.35 (d, 1H, J = 6 Hz), 4.20-4.06 (m, 3H), 3.89-3.83 (m, 1H), 3.67- 3.59 (m, 1H), 3.57-3.47 (m, 2H), 2.18 (s, 3H), 2.00 (s, 3H), 1.97 (s, 3H), 1.95 (s, 3H).^{13}C NMR (100 MHz, $CDCl_3$): δ 170.2, 169.7, 169.6, 165.4, 151.8, 146.5, 136.4, 132.1, 129.2, 128.5, 127.9 127.4, 124.5, 122.9, 116.9, 101.2, 76.4, 71.2, 70.4, 68.7, 68.5, 67.1, 61.2, 39.4, 20.7, 20.6; HRMS (MALDI-ToF) (*m/z*); calcd. for $C_{37}H_{41}NO_{13}Na$ 730.2476; found:730.2476 $[M+Na]^+$.

2,3-bis(hydroxy)-*N*-*α*-D-mannopyranoside-ethylbenzamide 10. General procedure B with 2,3-*bis*(benzyolxy)-*N*- 2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethylbenzamide **9** (0.1 g, 0.14 mmol), sodium methoxide (45 mg, 0.8 mmol) and 10 % Pd/C (10 mg) yielded 2,3-bis(hydroxy)-*N*- *α*-D-mannopyranoside-ethylbenzamide **10** (32 mg, 64%). $[\alpha]_D^{r.t}$ = +39.8 (c = 1.0, H_2O); ^{1}H NMR (400 MHz, MeOD): δ 7.26 (d, 1H, *J* = 9.2 Hz), 6.92 (d, 1H, *J* = 8.0 Hz), 6.73 (t, 1H, *J* = 8.0 Hz), 4.82 (s, 1H), 3.94-3.75 (m, 3H), 3.75-3.51 (m, 7H). ^{13}C NMR (100 MHz, MeOD): δ 169.9, 148.3, 145.5, 118.1, 117.7, 115.6, 73.5, 71.2, 70.7, 67.1, 65.8, 61.4, 39.1. HRMS (MALDI-ToF) (*m/z*); calcd. for $C_{15}H_{21}NO_9Na$ 382.1114; found:382.0784 $[M+Na]^+$

2,3-bis(hydroxy)-*N*- *β*-D-galactopyranoside-ethylbenzamide 13. General procedure B with 2,3-bis(benzyolxy)-*N*- 2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethylbenzamide **12** (90 mg,

0.12 mmol), sodium methoxide (40 mg, 0.75 mmol) and 10 % Pd/C (10 mg) yielded 2,3-bis(hydroxy)-*N*- α-D-mannopyranoside-ethylbenzamide **13** (35 mg, 77%). $[\alpha]_D^{r.t}$ = +21.8 (c = 1.0, H_2O); ^1H NMR (400 MHz, MeOD): δ 7.26 (d, 1H, J = 9.2 Hz), 6.93 (d, 1H, J = 8.0 Hz), 6.73 (t, 1H, J = 8.0 Hz), 4.31 (d, 1H, J = 8.0 Hz), 4.05-3.95 (m, 2H), 3.84-3.47 (m, 8H). ^{13}C NMR (100 MHz, MeOD): δ 170.1, 145.9, 144.5, 118.3,117.5, 103.8, 75.4, 73.5, 71.2, 68.9, 68.1, 61.1, 39.4. HRMS (MALDI-ToF) (*m/z*); calcd. for $C_{15}H_{21}NO_9Na$ 382.1114; found:382.0784 $[M+Na]^+$



Scheme 2. Reagents and Conditions: (a) TFA/DCM; 2,3-bis(benzyolxy)-benzoic acid, DIC/HOBT/DCM; (b) 1N NaOH/MeOH; pentafluorophenol (PFP)/DIC/DCM; (c) Comp **8 or 11**/DCM/TEA; (d) NaOMe/MeOH; H_2/Pd-C/MeOH. (e) $FeCl_3$/MeOH.

2,3-bis(benzyolxy)-3-{*N*-{tris[3-[ethylcarboxyl-ethoxy)methyl]}methylamide}-3-ethyl benzamide (15). *tert*-butoxycarbonyl-3-{*N*-{tris[3-[ethylcarboxyl-ethoxy) methyl]}methylamide}-3-*β*-alanine **14** (3 g, 5.06 mmol) was dissolved in dichloromethane/trifluoroacetic acid (3:1, 10 mL) and stirred at room temperature for 1 h. The solvent was evaporated *in vacuo*, the residue was re-dissolved in anhydrous dichloromethane (25 mL) and the pH adjusted to 8 using triethylamine. 2,3-bis(benzyolxy)-benzoic acid (2.5 g, 7.6 mmol) and diisopropyl carbadiazine (1.2 ml, 7.6 mmol) were added to the above mixture and stirred for 12 h at rt. Finally, the mixture was concentrated *in vacuo* and purified by flash chromatography (DCM:MeOH; 95:5) to afford 2,3-bis(benzyolxy)-3-{*N*-{tris[3-[ethylcarboxyl-ethoxy)methyl]} methylamide}-3-ethyl benzamide **15**. (2.4 g, 60%). R_f = 0.5 (CH_2Cl_2/MeOH, 98:5); ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.2 (t, 1H, J = 8.0 Hz), 7.62 (t, 2H, J = 4.0 Hz), 7.45-7.27 (m, 9H), 7.12 (t, 3H, J = 8.0 Hz), 5.12 (s, 2H), 5.08 (s, 2H), 4.12 (q, 6H, J = 8.0 Hz), 3.64 (s, 6H), 3.61 (t, 6H, J =8.0 Hz), 3.54 (q, 2H, J =8.0 Hz), 2.46 (t, 6H, J =8.0 Hz), 2.34 (t, 2H, J = 8.0 Hz), 1.23 (t, 9H, J =8.0 Hz). ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.7, 169.9, 169.8, 165.4, 151.7, 149.9, 136.4, 132.2, 128.9, 128.8, 127.7, 127.1, 124.4, 123.2, 117.3, 70.8, 68.9, 65.9, 60.3, 60.1, 53.4, 41.8, 38.1, 35.4, 24.9. HRMS (MALDI-ToF) (*m/z*); calcd. for $C_{43}H_{56}N_2O_{13}Na$ 831.3680; found:831.3682 $[M+Na]^{+\cdot}$

2,3-bis(benzyolxy)-2-carbonyl-3-{*N*-{tris[3-[pentafluoro phenyl carboxyl-ethoxy) methyl]}methylamide}-3-ethyl benzamide 16. To a solution of 2,3-bis(benzyolxy)-3-{*N*-{tris[3-[ethylcarboxyl-ethoxy)methyl]} methylamide}-3-ethyl benzamide **15.** (1.5 g, 1.86 mmol) in methanol (10 mL) was added NaOH (aqueous, 1 N, 3 mL) The mixture was stirred at rt for 2 h, concentrated *in vacuo*, adjusted to pH 5 with HCl (aqueous, 1 N) and extracted with EtOAc. The organic layer was dried with Na_2SO_4, filtered and concentrated *in vacuo*. The residue was dissolved in DCM and 2,3,4,5,6-pentafluorophenol (1.69 g, 9.3 mmol) was added. After cooling to 0 $^{\circ}$C, diisopropyl carbadiazine (1.6 mL, 10.2 mmol) was added and the reaction mixture was stirred for 12 h at room temperature, concentrated *in vacuo* and purified by silica column flash

chromatography (DCM:EtOAc; 92:8) to afford 8-*O*-benzyl-quinoline-2-carbonyl-3-{*N*-{tris[3-[pentafluoro phenyl carboxyl-ethoxy)methyl]}methylamide}-3-*β*-alanine (1.3 g, 59%). R_f = 0.5 (CH_2Cl_2/EtOAc, 90:10); ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.27 (t, 1H, *J* = 8.0 Hz), 7.63 (t, 2H, *J* = 4.0 Hz) 7.45-7.27 (m, 9H), 7.14 (t, 2H, *J* = 8.0 Hz), 5.13 (s, 2H), 5.09 (s, 2H), 4.45 (br,1H), 3.73 (m, 12H), 3.54 (q, 2H, *J* =8.0 Hz), 2.81 (t, 6H, *J* =8.0 Hz), 2.32 (t, 2H, *J* = 8.0 Hz). ^{13}C NMR (100MHz, $CDCl_3$): δ 170.4, 169.9, 169.8, 165.2, 152.4, 149.2, 142.3, 142.3, 140.1, 139.3, 136.7, 128.9, 127.2, 122.1, 118.7, 75.9, 75.6, 70.8, 65.1, 60.2, 54.2, 38.8, 35.2. HRMS (MALDI-ToF) (*m/z*); calcd. for $C_{55}H_{41}N_2O_{13}F_{15}$ 1222.2369; found: 1222.2365 $[M]^{+\cdot}$

2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-[2-ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3- ethyl benzamide (14). General procedure A using 2-(*tert*-butoxycarbonylamino)ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside **21** (0.2 g, 0.41 mmol) and 8-*O*-benzyl-quinoline-2-carbonyl-3-{*N*-{tris[3-[pentafluoro phenyl carboxyl-ethoxy) methyl]}methylamide}-3-*β*-alanine **11** (0.1 g, 0.082 mmol). Purification by flash chromatography (DCM:MeOH; 94:6) yielded 8-*O*-benzyl-quinoline-2-carbonyl-3-{tris[3-[2-ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine (0.087 g, 58%). R_f = 0.5 (CH_2Cl_2/MeOH, 92:8); $[\alpha]_D^{r.t}$ = +21.1 (c = 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, MeOD): δ 8.20 (t, 1H, *J* = 4.0 Hz), 7.72-7.62 (m, 2H), 7.50-7.30 (m, 9H), 7.18-7.10 (t, 2H), 5.26-5.21 (m, 9H), 5.13 (s, 2H), 5.09 (s, 2H), 4.23 (dd, 3H, *J* = 4.8, 8.0 Hz), 4.09 (dd, 3H, *J* = 2.4, 9.6 Hz), 4.02-4.01 (m, 3H), 3.73-3.71 (m, 6H), 3.65 (br.s, 6H), 3.61 (t, 6H, *J* = 6.0 Hz), 3.53-3.50 (m, 9H), 3.38 (t, 6H, *J* = 4.5 Hz), 2.62 (t, 2H, *J* = 6.9 Hz), 2.35 (t, 6H, *J* = 6.0 Hz), 2.10 (s, 9H), 2.03 (s, 9H), 2.01 (s, 9H), 1.91 (s, 9H); ^{13}C NMR (100 MHz, MeOD): δ 170.2, 169.7, 169.6, 165.4, 151.8, 146.5, 136.4, 132.1, 129.2, 128.5, 127.9 127.4, 124.5, 122.9, 116.9, 101.4, 71.8, 70.4, 70.2, 69.7, 69.3, 69.0, 63.1, 40.1, 38.3, 31.0, 20.4; (MALDI-ToF) (*m/z*): $[M+Na]^+$ calcd. for $C_{85}H_{113}N_5O_{40}Na$ 1866.6860; found:1866.6934.

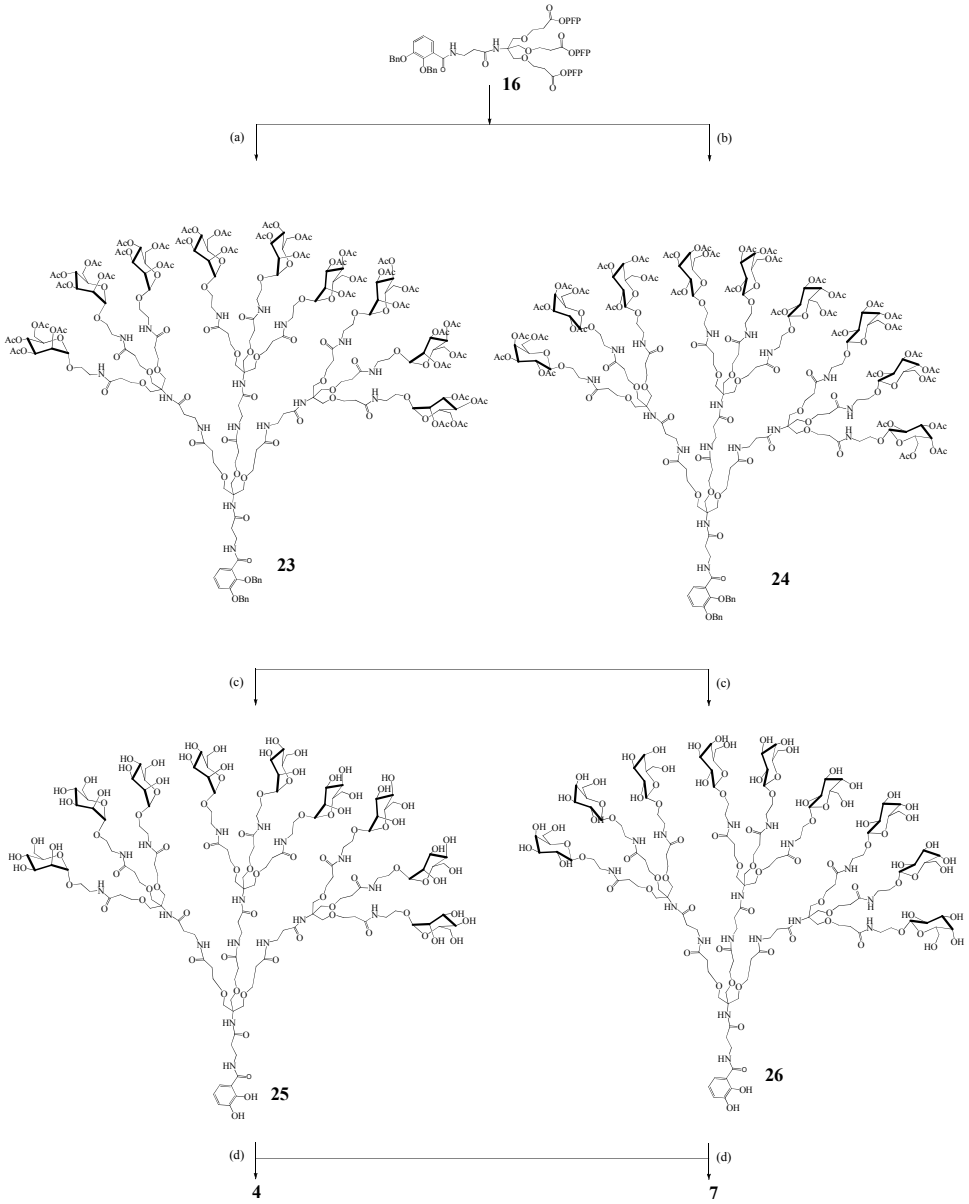
(vii) 2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-[2-ethoxy-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine 18. General procedure A using 2-(*tert*-butoxycarbonylamino)ethoxy-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside **22** (0.2 g, 0.41 mmol) and 8-*O*-benzyl-quinoline-2-carbonyl-3-{*N*-{tris[3-[pentafluoro phenyl carboxyl-ethoxy) methyl]}methylamide}-3-*β*-alanine **11** (100 mg, 0.08 mmol). Purification column chromatography yielded 2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-[2-ethoxy-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethoxy]methyl] methylamide}-3-*β*-alanine (0.064 g, 42%). R_f =

0.5 (CH_2Cl_2/MeOH, 92:8); $[\alpha]_D^{r.t}$ = +18.7 (c = 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, MeOD): δ 8.20 (t, 1H, *J* = 4.0 Hz), 7.72-7.62 (m, 2H), 7.50-7.30 (m, 9H), 7.18-7.10 (t, 2H), 5.37 (d, 3H, *J* = 4.0 Hz), 5.27 (s, 2H), 5.14 (t, 5H, *J* = 8.0 Hz), 4.99 (dd, 3H, *J*= 4.0 Hz), 4.49 (d, 3H, *J* = 8.0 Hz), 4.12-4.10 (m, 6H), 3.92 (t, 3H, *J* = 6.0 Hz), 3.84 (d, 3H, *J* = 4.0 Hz), 3.65 (br.s, 18H), 3.42 (m, 9H), 3.34-3.31 (m, 2H), 2.39 (t, 6H, *J* = 6.0 Hz), 2.14 (s, 9H), 2.04 (s, 9H), 2.02 (s, 9H), 1.96 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.1, 170.0, 169.8, 169.7, 155.3, 149.4, 139.7, 138.6, 131.6, 129.3, 128.7, 128.1, 119.9, 112.2, 101.1, 70.6, 69.1, 68.7, 67.2, 66.9, 61.2, 59.7, 39.1, 37.0, 30.4, 20.6; (MALDI-ToF) (*m/z*): $[M+Na]^+$ calcd. for $C_{85}H_{113}N_5O_{40}Na$ 1866.6860; found:1866.6934.

2,3-bis(hydroxy)-2-carbonyl-3-{tris[3-[2-ethoxy-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine 19. General procedure B with 2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-[2-ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethoxy]methyl] methylamide}-3-*β*-alanine **17** (70 mg, 0.038 mmol), sodium methoxide (12 mg, 0.27 mmol) and 10 % Pd/C (10 mg) yielded 2,3-bis(hydroxy)-2-carbonyl-3-{tris[3-[2-ethoxy-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine **19** (19 mg, 43%). $[\alpha]_D^{r.t}$ = + 5.4(c = 1.0, H_2O); ^{1}H NMR (400 MHz, MeOD): δ 7.26 (d, 1H, *J* = 8.0 Hz), 6.92 (d, 1H, *J* = 8.0 Hz), 6.74 (d, 1H, *J* = 8.0 Hz),4.75 (s, 3H), 3.81 (d, 6H, *J* = 7.8 Hz), 3.72-3.67 (m, 12H), 3.64-3.54 (m, 18H), 3.53-3.49 (m, 8H), 2.62 (t, 2H, *J* = 6.9 Hz), 2.33 (t, 6H, *J* = 6.0 Hz); ^{13}C NMR (100 MHz, MeOD): δ 170.1, 145.9, 144.5, 118.3,117.5, 101.2, 74.3, 71.6, 69.6, 68.2, 66.8, 62.3, 61.1, 39.9, 37.0; (MALDI-ToF) (*m/z*); $[M+Na]^+$ calcd. for $C_{47}H_{77}N_5O_{28}Na$ 1182.4653; found:1182.6038.

2,3-bis(hydroxy)-2-carbonyl-3-{tris[3-[2-ethoxy-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine 20 : General procedure B with 2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-[2-ethoxy-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethoxy]methyl] methylamide}-3-*β*-alanine **18** (40 mg, 0.022 mmol), sodium methoxide (7 mg, 0.132 mmol) and 10% Pd/C (10 mg) yielded 2,3-bis(hydroxy)-2-carbonyl-3-{tris[3-[2-ethoxy-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine (13 mg, 54%). $[\alpha]_D^{r.t}$ = +13.9 (c = 1.0, H_2O); ^{1}H NMR (400 MHz, MeOD): δ 7.26 (d, 1H, *J* = 8.0 Hz), 6.92 (d, 1H, *J* = 8.0 Hz), 6.74 (d, 1H, *J* = 8.0 Hz), 4.29 (d, 3H, *J* = 7.5 Hz), 3.82-3.55 (m, 44H), 2.61 (t, 2H, *J* = 6.9 Hz), 2.33 (t, 6H, *J* = 6.0 Hz); ^{13}C NMR (100 MHz, MeOD): δ 170.1, 145.9, 144.5, 118.3,117.5,103.5,

75.0, 72.6, 70.6, 68.5, 63.2, 48.9, 39.3, 35.8; (MALDI-ToF) (*m/z*); $[M+Na]^+$ calcd. for $C_{47}H_{77}N_5O_{28}Na$ 1182.4653; found:1182.6038.



Scheme 3. Reagents and Conditions: (a) Comp **22 or 23**/DCM/TEA; (d) NaOMe/MeOH; H_2/Pd-C/MeOH. (e) $FeCl_3$/MeOH.

5. Synthesis of ligand 25 and 26.

2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-carboxyl ethoxy]methyl] 3'-{tris[2'-ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine 22. General procedure A using *tert*-butoxycarbonyl-3-{tris[3-[2-ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-

mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine **23** (66 mg, 0.041 mmol), 2,3-bis(benzyolxy)-2-carbonyl-3-{*N*-{tris[3-[pentafluoro phenyl carboxyl-ethoxy) methyl]}methylamide}-3-*β*-alanine **16** (10 mg, 8.1 µmol) and flash silica column chromatography to afford 2,3-(benzyolxy)-2-carbonyl-3-{tris[3-carboxylethoxy]methyl]3'-{tris[2'-ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine (15 mg, 65%). R_f = 0.5 (CH_2Cl_2/MeOH, 90:10); $[\alpha]_D^{r.t}$ = -9.1 (c = 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, MeOD): *δ* 7.59 (t, 1H, *J* = 8.4 Hz), 7.39 (m, 1H), 7.45-7.28 (m, 10H), 7.10 (t, 1H, *J* = 8.0 Hz), 5.45 (s, 2H), 5.21-5.26 (m, 27H), 4.23 (dd, 9H, *J* = 4.8, 7.2 Hz), 4.09 (dd, 9H, *J* = 2.4, 9.6 Hz), 4.03-4.01 (m, 14H), 3.70-3.62 (br.s, 54H), 3.55 (s, 28H), 3.45 (br.s, 32H), 2.45 (t, 28H, *J* = 6.0 Hz), 2.13 (s, 27H), 2.05 (s, 27H), 2.03 (s, 27H), 1.95 (s, 27H); ^{13}C NMR (100 MHz, MeOD): *δ* 171.8, 171.6, 170.5, 167.0, 169.6, 166.2, 155.3, 149.7, 141.6, 140.1, 139.6, 129.9, 129.3, 128.6, 120.9, 120.1, 112.9, 102.2, 74.5, 72.2, 69.0, 68.9, 68.5, 67.2, 64.9, 62.3, 55.8, 39.8, 36.3, 20.8. MALDI-TOF (*m/z*): calcd. for $C_{225}H_{324}N_{18}O_{120}Na$ 5220.9696; found: 5220.956 $[M+Na]^+$.

2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-carboxyl ethoxy]methyl] 3'-{tris[2'-ethoxy-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine 24. General procedure A using *tert*-butoxycarbonyl-3-{tris[3-[2-ethoxy-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine **23** (0.60 g, 0.039 mmol), 2,3-bis(benzyolxy)-2-carbonyl-3-{*N*-{tris[3-[pentafluoro phenyl carboxyl-ethoxy) methyl]} methylamide}-3-*β*-alanine **16** (10 mg, 8.1 µmol) and purification by flash silica column chromatography afforded 2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-carboxyl ethoxy]methyl] 3'-{tris[2'-ethoxy-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine (15 g, 66%). R_f = 0.5 (CH_2Cl_2/MeOH, 90:10); $[\alpha]_D^{r.t}$ = -15.1 (c =1.0, $CHCl_3$); ^{1}H NMR (400 MHz, MeOD): *δ* 7.61 (t, 1H, *J* = 8.4 Hz), 7.39 (m, 1H), 7.45-7.28 (m, 10H), 7.10 (t, 1H, *J* = 8.1 Hz), 5.38 (d, 9H, *J* = 4.0 Hz), 5.10 (dd, 10H, *J* = 4.0, 8.0 Hz), 4.48 (d, 9H, *J* = 4.0 Hz), 4.13 (d, 32H, *J* = 6.9 Hz), 3.87 (br.s, 9H), 3.66 (br.s, 78H), 3.39-3.36 (m, 24H), 2.43 (br, 32H), 2.13 (s, 27H), 2.05 (s, 27H), 2.01 (s, 27H), 1.94 (s, 27H); ^{13}C NMR (100 MHz, MeOD): *δ* 168.8, 167.0, 169.6, 166.2, 150.3, 149.4, 139.7, 133.6, 132.8, 131.6, 129.3, 128.6, 126.9, 97.5,70.7, 70.3, 69.5, 69.2, 69.0, 68.9, 68.5, 63.7, 62.3, 53.3, 39.8, 35.3, 20.8; MALDI-TOF (*m/z*): calcd. for $C_{225}H_{324}N_{18}O_{120}Na$ 5220.9696; found: 5220.956 $[M+Na]^+$.

2,3-bis(hydroxyl)-2-carbonyl-3-{tris[3-carboxyl ethoxy]methyl] 3'-{tris[2'-ethoxy-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine 5. General procedure B using 2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-carboxylethoxy]methyl]3'-{tris[2'-ethoxy-2,3,4,6-tetra-*O*-acetyl-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine (15 mg, 2.8 µmol), sodium methoxide (10 mg, 2 µmol) and Pd/C (10 mg) yielded 2,3-bis(hydroxyl)-2-carbonyl-3-{tris[3-[2-ethoxy-*α*-D-mannopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine (10 mg, 69%). $[\alpha]_D^{r.t}$ = +51.2 (c = 1.0, H_2O); ^{1}H NMR (400 MHz, D_2O): δ 7.26 (d, 1H, J = 9.2 Hz), 6.92 (d, 1H, J = 8.0 Hz), 6.73 (t, 1H, J = 8.0 Hz), 4.85 (s, 9H), 3.81-3.52 (m, 112H), 3.46-3.31 (m, 37H), 2.45 (t, 18H, J = 8.0 Hz), 2.39-2.33 (m, 12H); ^{13}C NMR (100 MHz, D_2O): δ 176.7, 173.8, 148.3, 145.5, 128.6, 119.6, 118.6, 115.5, 101.2, 74.3, 71.6, 69.6, 68.2, 66.8, 62.3, 61.1, 39.9, 37.0; (MALDI-ToF) (*m/z*); $C_{143}H_{245}N_{17}O_{85}Na$ 3583.5269; found : 3583.5234 $[M+Na]^+$.

2,3-bis(hydroxyl)-2-carbonyl-3-{*tris*[3-carboxylethoxy]methyl]3'-{*tris*[2'-ethoxy-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine 6. General procedure B using 2,3-bis(benzyolxy)-2-carbonyl-3-{tris[3-carboxyl ethoxy]methyl]3'-{tris[2'-ethoxy-2,3,4,6-tetra-*O*-acetyl-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine (15 mg, 2.8 µmol), sodium methoxide (10 mg, 2.4 µmol) and 10% Pd/C (12 mg) yielded 2,3-bis(hydroxy)-2-carbonyl-3-{*tris*[3-carboxylethoxy]methyl]3'-{*tris*[2'-ethoxy-*β*-D-galactopyranoside-ethoxy]methyl]methylamide}-3-*β*-alanine **6** (10 mg, 69%). $[\alpha]_D^{r.t}$ = -24.3 (c = 1.0, H_2O); ^{1}H NMR (400 MHz, MeOD): δ 7.26 (d, 1H, J = 9.2 Hz), 6.92 (d, 1H, J = 8.0 Hz), 6.73 (t, 1H, J = 8.0 Hz), 4.35 (d, 9H, J = 8.0 Hz), 3.88 (m, 18H), 3.72-3.55 (m, 118H), 3.55-3.36 (m, 37H), 2.45 (t, 18H, J = 8.0 Hz), 2.39 (t, 8H, J = 9.2 Hz), 2.23 (t, 4H, J = 8.0 Hz); ^{13}C NMR (100 MHz, MeOD): δ 176.7, 173.6, 162.3, 149.5, 145.6, 118.6, 118.1, 115.5, 75.0, 72.6, 70.6, 68.5, 67.2, 60.9, 39.3, 35.8; (MALDI-ToF) (*m/z*); $C_{143}H_{245}N_{17}O_{85}Na$ 3583.5269; found : 3583.5234 $[M+Na]^+$.

6. Ligand titration with Ferric Ions. Aliquots of stock solutions of the ligands **10, 19, 25** and increasing amounts of $FeCl_3$ (both in spectroscopic grade methanol) were mixed, and after 15 min diluted with methanol/0.1 N aqueous tris-buffer pH 8.5 (4/1) to a constant ligand concentration of 0.3 mM for UV/vis titrations. Measurements were performed after equilibration

for 24 h at room temperature. UV/vis absorption spectra were recorded on a Hewlett-Packard diode array 8450A spectrophotometer.

Spectral evidence for the formation of the 3:1 complexes for catechol from iron(III) in air-saturated buffers is shown in figure 1 for complex **2** at 490 nm.

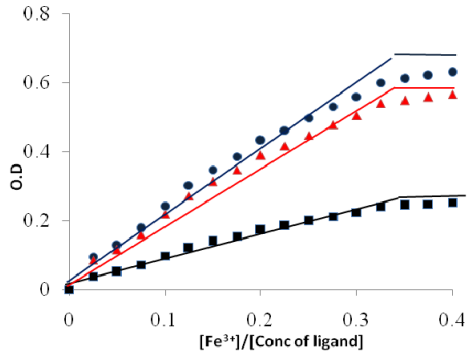


Figure 1. Uv-visible spectroscopic titrations of ligands: Variation of $O.D_{490}$ intensity as a function of the molar Iron(III)/ligand fraction. Solvent: methanol/water(80:20); ligand concentration = 0.3 mM; 0.05 M (tris-base, pH 8.0); *T* (25.0 ± 0.2) °C, **10 (●), 19(▲), 25 (■).**

7. Tubidimetric analysis :

The solution of lectin (1.0 mg/ml) in HEPES buffer (10 mM Hepes pH 6.5, 1mM $MgCl_2$, 1mM $CaCl_2$, 1% BSA) and complex 6-12 (1.0 mM) in water was added. The time dependent turbidity kinetics was recorded by measuring the absorption coefficient at 700 nm after every one minutes. After 20 minutes the turbidity was disturbed by adding 100 mM of mannose to the solution.

8. Imaging Experiment :

The snapshot experiment was performed with 1 mM of **4** and **7** complex and 5 mg/mL (0.1 ml) of ConA lectin in HEPES buffer solution (10 mM Hepes pH 6.5, 1mM $MgCl_2$, 1mM $CaCl_2$, 1% BSA). Complex **4** showed precipitation with ConA after 1 hr.

4 **7**

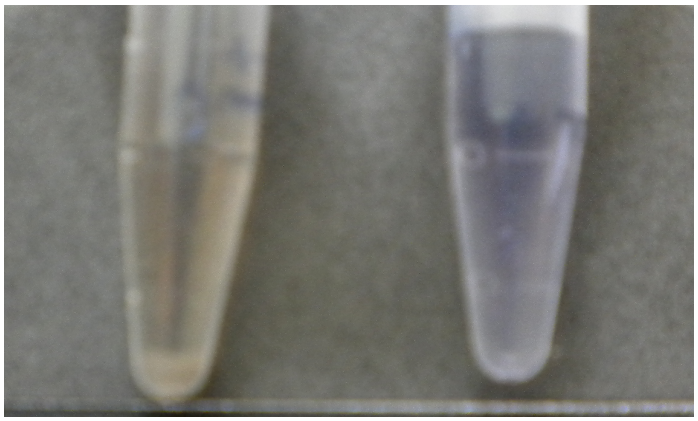


Figure 2. Visible images of the complex **4** & **7** in presence and absence of ConA lectin.

9. Bacterial Strains and 96-well growth promotion assay. The mutants *E.coli ORN178 and ORN208* were provided by Prof. Orndorff (College of Veterinary Medicine, Raleigh, NC United States). Such mutants are ideal for the study of mannose mediate interactions. Bacteria were grown in LB medium overnight at 37 °C on a rotary shaker at 180 RPM. An aliquots of bacteria were removed from the batch culture to monitor growth until they reached an approximate OD_{600} of 0.6. Approximately 100 µL of bacterial cells were aliquot in to previously autoclaved 2.2 ml 96-well polypropylene blocks and the mixed with 1ml of freshly prepared LB broth medium containing 0.1 mM of 2,2'-dipyridyl, followed by 0.1µM to 0.1 mM concentration of iron complexes (**1-7**). After covering the arrays with a sterile mat cap, the cultures were placed on a rotating platform shaker at 250 rpm and incubated at 37°C for at least 6 h. Figure 4 displayed the optimum concentration required for bacterial growth.

Once we optimum concentration of the ligand (50 µM) for different rate of growth. 96-plate assay was repeated at different time interval to monitor the kinetics of growth. The inhibition assay was performed by adding NaN_3 (100 µM) or compound **4** (50 µM) before adding 50 µM of iron complexes (**1-7**).

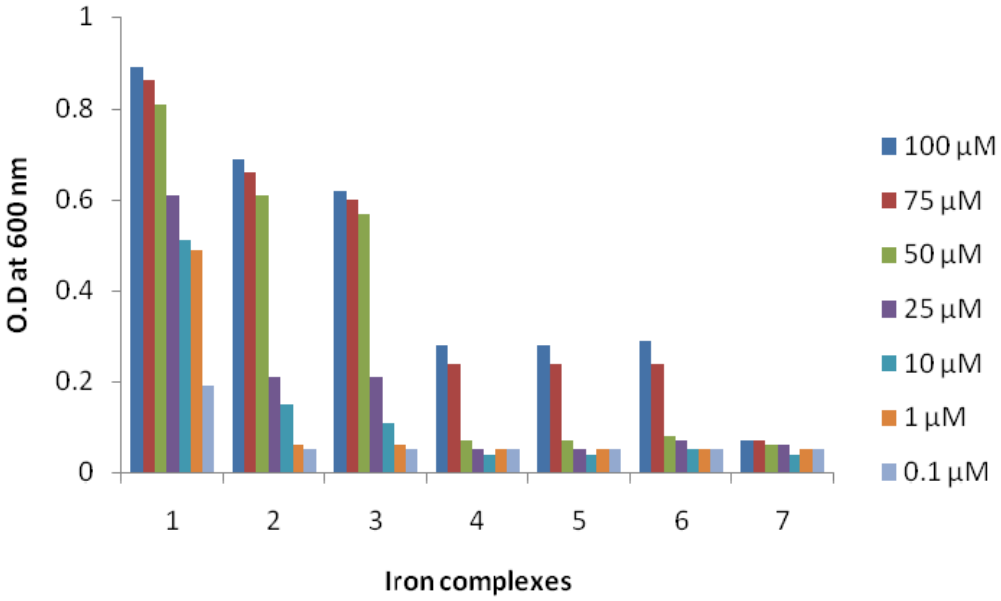


Figure 3. Fe(III)-glycodendrimer dependent growth promotion under iron limitation. Mannose positive mutants of *E. coli* (ORN178) was grown in a medium containing the iron chelator 2,2'-dipyridyl with different concentration of complex **1-7**. A_{600} value represent the means ± standard deviations from there parallel cultures.

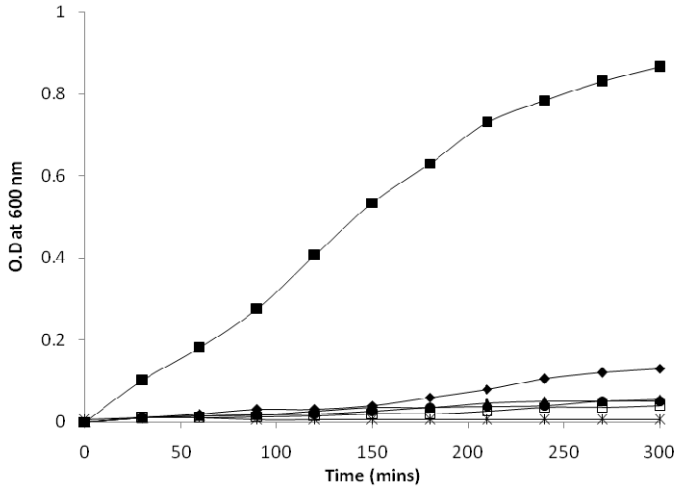


Figure 4. Fe(III)-glycodendrimer dependent growth promotion under iron limitation. Mannose negative mutants of *E. coli* (ORN208) was grown in a medium containing the iron chelator 2,2'-dipyridyl (×) siderophore **1**(■), complex 2(♦), 3(●), 4 (□), 5 (◊) and 7 (○). A_{600} value represent the means ± standard deviations from their parallel cultures.

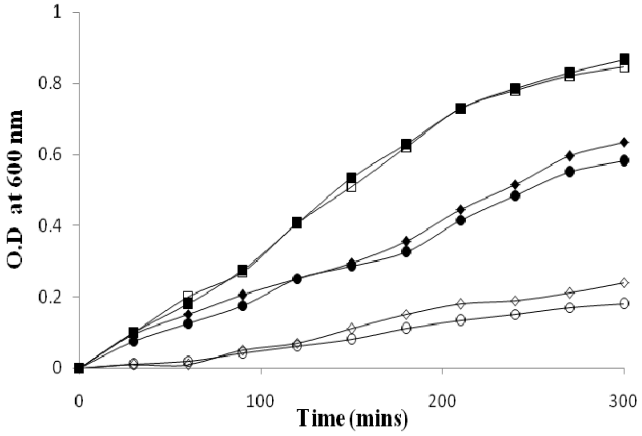


Figure 5. Fe(III)-glycodendrimer dependent growth promotion under iron limitation. Mannose positive mutants of *E. Coli* (ORN178) was grown in medium containing the iron chelator 2,2'-dipyridyl and compound **1**(■),2(♦)3(●) and with complex **4**, (50 μM) for 30 mins and complex **1**(□), 2 (◊) and 3 (○). A_{600} value represent the means ± standard deviations from their parallel cultures.

10. LB Plate assay. LB plate assay for performed according to earlier protocols.[2] All stains were tested on plates containing bipyridine (100 mM). Sterile aqueous solution of siderophore were prepared in the concentration of 0.1 mM and added on autoclaved circular filter papers. Plates were incubated for 24h. The radiuses of bacterial growth around the filter papers indicate specific update and delivery of iron into the system (fig 6).

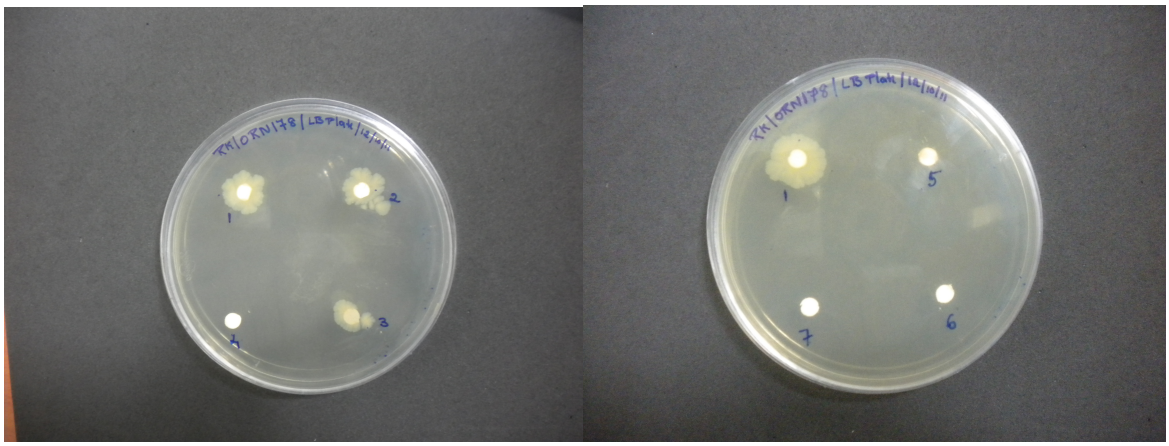


Figure 6. LB plates assay with compound **1-7** and *E. coli* ORN 178 stain.

11. References

1. R. Kikkeri, L. H. Hossain, P. H. Seeberger, *Chem Comm.* 2008, 2127

2. W. Rabsch, G. Winkelmann, *BioMetals*, 1991, **4**, 244.