7. Experimental Part

7.1 Synthesis of Bolaamphiphiles

Ethyl 14-hydroxy-3,6,9,12-tetraoxatetradeconate (1)

Under argon atmosphere tetraethylene glycol (TEG) (30g) was treated with sodium (1.8 g, 78 mmol) in a 500 ml three neck flask. The reaction mixture was heated up to 120^{o}C. The reaction was controlled at constant temperature i.e.120^{o}C by using a temperature controller. The mixture was stirred until all of the sodium was dissolved at the same temp. Then ethyl bromoacetate (12.5 g, 74 mmol) was added slowly and the reaction mixture was heated at 120^{o}C overnight. The suspension was cooled to room temperature, diluted with water and washed with diethyl ether. The aqueous fractions were washed with methylene chloride. Then the methylene chloride fractions were washed with water which in turn was washed with methylene chloride. The aqueous phase was removed under vacuum. Using toluene the residual oil was dried azeotropically and the crude yellow oil obtained was purified by column chromatography on silica gel, yielded 74% of **1**.

$C_{12}H_{24}O_7$ (Mo. Wt. 280)

^{1}H-NMR ($CDCl_3$, 250 MH_Z): δ= 4.15 (q, J= 7.1, 2H; $O\underline{CH_2}CH_3$), 4.08 (s, 2H; $\underline{CH_2}CO$), 3.5-3.7 (m, 14 H; CH_2 of OEG chain), 2.95 (bs, 1H, OH), 1.22 (t, J=7.1, 3H; $\underline{CH_3}CH_2O$)

IR (KBr) cm^{-1}: 3399 (O-H stretching of primary alcohol), 2912 and 2877 (C-H stretching of CH_2CH_3), 1745 (C=O stretching of ester), 1456 and 1349 (C-H bending of CH_2CH_3), 1289 (C-O stretching of ester), 1248 and 1219 (C-O stretching of ethers) 945, 887.

MASS (Xe, pos-FAB): $C_{12}H_{24}O_7$ (Mo. Wt. 280); [m/z]: 281 $[M+H]^+$.

Ethyl 14- azido-3,6,9,12-tetroxatetradeconate (2)

Ethyl 14-hydroxy-3,6,9,12-tetraoxatetradeconate **1** was dissolved in dry dichloromethane (40 ml) and added methane sulfonyl chloride (1.37ml, 12mmole). The reaction mixture was stirred at room temperature. Triethylamine (3.09ml, 30mmole)was added slowly to it and the stirring was continued for further 1hr. The mixture was filtered and the filtrate was removed in vacuo. Then toluene was added to it successively three times to remove residual methylene chloride by using rotavap.

The obtained mesilyated product was dissolved in dry ethanol (30 ml) and added sodium azide (0.91 g, 14 mmol) to it. The mixture was refluxed for 4 hrs. Then water was added periodically and the reaction mixture was stirred at room temperature overnight. The mixture was diluted with water and extracted with dichloromethane, dried over anhydrous magnesium sulphate , filtered and solvent was removed in vacuo. The residue was purified by column chromatography (Toluene/AcoEt 10:1 to 0:1) ethyl 14- azido-3,6,9,12-tetroxatetradeconate **2** as an yellow oil (92%).

$C_{12}H_{23}N_3O_6$ (Mo. Wt. 305)

^{1}H-NMR ($CDCl_3$, 250 MH_Z): δ = 4.14 (q, J=7.2Hz, 2H; O$\underline{CH_2}CH_3$); 4.07 (s, 2H; $\underline{CH_2}CO$); 3.5-3.8 (m, 14H; $\underline{CH_2}$ of OEG-chain); 3.31 (t, J=5Hz, 2H; $\underline{CH_2}N_3$); 1.25 (t, J=7.2 Hz, 3H; $\underline{CH_3}$ of ester).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 170.28, 71.83, 71.28, 70.83, 70.51, 69.72, 68.94, 68.88, 60.64, 50.63, 42.60, 14.09.

IR (KBr) cm^{-1}: 3488 (overtone of C=O stretching), 2912 and 2872 (C-H stretching of CH_2CH_3), 1751 (C=O stretching of ester), 1453 and 1384 (C-H bending of CH_2CH_3), 1286 (C-O stretching of ester), 1251 and 1205 (C-O stretching of ethers), 1120 (C-N stretching), 723 (methylene rock).

MASS (Xe, pos-FAB in $CDCl_3$): $C_{12}H_{23}N_3O_6$ (Mo. Wt. 305); [m/z]: 306 $[M+H]^+$.

Ethyl 14-amino-3,6,9,12-tetraoxatetradecanoate (3)

Ethyl 14- azido-3,6,9,12-tetroxatetradeconate **2** (3.43 g, 11.2 mmol) was dissolved in 30 ml dry THF. The mixture was cooled to 0 ^{o}C on an ice bath, triphenyl phoshine (3.027 g, 11.5 mmol) was added and the mixture was stirred for 24 hrs warming to room temperature. TLC [*i*-PrOH/ aq. NH_3 (5%)/ H_2O 6:3:1] showed conversion to the new adduct. To hydrolyze the intermediate phosphorous adduct water (1 ml) was added and the reaction mixture was stirred overnight at room temperature. The mixture was diluted with water and washed with toluene. The aqueous layer was evaporated yields ethyl 14-amino-3,6,9,12-tetraoxatetradecanoate **3** as slightly yellow oil in 85%.

TLC ($CHCl_3$ / MeOH / Et_3N 3 :3 :1) : R_f 0.52

$C_{12}H_{25}N_1O_6$ (Mo. Wt. 279)

^{1}H-NMR ($CDCl_3$, 250 MH_Z): δ = 5.25 (broad s, 2H ; NH_2); 4.14 (q, J=7.2Hz, 2H; OCH_2CH_3); 4.07 (s, 2H; CH_2CO); 3.45-3.71 (m, 14H; CH_2 of OEG-chain); 3.05 (t, 2H; CH_2NH_2); 1.18 (t, J=7.2 Hz, 3H; CH_3 of ester).

^{13}C NMR ($CDCl_3$, 125 MHz): δ =170.28, 72.41, 70.72, 70.38, 70.14, 69.70, 68.79, 68.35, 63.58, 60.81, 39.35, 14.09

IR (KBr) cm^{-1}: 3439 (N-H stretching of primary amine), 2912 and 2877 (C-H stretching of CH_2CH_3), 1745 (C=O stretching of ester), 1600 (N-H bending of amine), 1456 and 1349 (C-H bending of CH_2CH_3), 1215 (C-O stretching of ester), 1111 (C-N stretching of amine), 943, 835 and 772 (N-H wagging).

MASS (Xe, pos-FAB): $C_{12}H_{25}N_1O_6$ (Mo. Wt. 279): [m/z] 279.8$(M+H)^+$

ElementalAnalysis: $C_{12}H_{25}N_1O_6$ (Mo. Wt. 279);

Calculated: 51.61 % C, 8.96 % H, 5,01 % N
Found : 51.64 % C, 7.51 % H, 5.73 % N

(2-{2-[2-(-2{-2[2-(2-Methoxy-ethoxy) ethoxy acetylamino}ethoxy)ethoxy] ethoxy} ethoxy) acetic acid ethyl ester (4)

2-[2-(2- Methoxy ethoxy) ethoxy] acetic acid (0.5519 ml, 3.5 mmol) and N-hydroxy succinimide (0.618 g, 5.4 mmol) were dissolved in dry dichloromethane (30 ml). The mixture was cooled on an ice bath. A solution of DCC (1.048 g, 5 mmol) in dry dichloromethane was slowly added in the cold, and the mixture was stirred for 1 hr with warming to room temperature. Ethyl 14-amino-3,6,9,12-tetraoxatetradecanoate **3** (1 g, 3.5mmol) dissolved in methylene chloride was added, followed by triethylamine (1.006 ml, 7.1 mmol). The mixture was stirred for half an hour at room temperature. TLC (MeOH / CH_2Cl_2 2:8) showed conversion to the new adduct. Dicyclohexylurea (DHU) was removed by filtration, and solvent was removed by evaporation. The residue was taken up in water, acidified, filtered and extracted with dichloromethane . The dichloromethane in turn was washed with water and dried over anhydrous magnesium sulphate, filtered and evaporation of solvent gave residual oil which was purified by column chromatography (MeOH/CH_2Cl_2 2:15) on silica gel : yields 76% as a yellow oil of **4**.

$C_{19}H_{37}N_1O_{10}$ (Mo. Wt. 439)

^{1}H-NMR ($CDCl_3$, 250 MH_Z): δ = 7.25 (broad s, 1H ; NH); 4.14 (q, 2H; OCH_2CH_3); 4.07 (s, 2H; CH_2CO); 3.95 (s, 2H, CH_2CONH); 3.40-3.81 (m, 22H; CH_2 of OEG-chain); 3.25 (s, 3H; CH_3O); 3.3 (t, 2H; CH_2NH); 1.18 (t, 3H; CH_3 of ester).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 169.69, 169.29, 71.94, 71.22, 70.64, 70.35, 70.17, 69.87, 69.64, 69.53, 69.06, 68.82, 68.26, 67.81, 63.10, 60.88, 53.19, 42.34, 13.49

IR (KBr) cm^{-1}: 3422 (N-H stretching of amide) , 2912 and 2875 (C-H stretching of CH_2CH_3), 1747 (C=O stretching of ester), 1669 (C=O stretching of amide), 1455 and 1350 (C-H bending of CH_2CH_3), 1286 (C-O stretching of ester), 1249 (C-O stretching of amide) 1112 (C-N stretching of amide), 722 (methylene rock).

MASS (Xe, pos-FAB in $CDCl_3$): $C_{19}H_{37}N_1O_{10}$ (Mo. Wt. 439); m/z: 439.9 $(M+H)^+$

ElementalAnalysis: $C_{19}H_{37}N_1O_{10}$ (Mo. Wt. 439);

Calculated: 51.93 % C, 8.42 % H, 3.18 % N

Found : 51.73 % C, 8.30 % H, 3.13 % N

(2-{2-[2-(-2{-2[2-(2-Methoxy ethoxy)ethoxy acetylamino} ethoxy) ethoxy] ethoxy} ethoxy) acetic acid (5)

A solution of sodium carbonate (0.96 g, 9.1 mmol) in water (30 ml) was added to a solution of (2-{2-[2-(-2{-2[2-(2-Methoxy ethoxy) ethoxy acetylamino}ethoxy) etho xy] ethoxy}ethoxy) acetic acid ethyl ester **4** (1 g; 2.2 mmol). The reaction mixture was heated at 50 ^oC for 2 hours. The mixture was cooled; washed with dichloromethane; acidified to pH = 3 with 1 N HCl and extracted with metylene chloride. The extract was dried over anhydrous magnesium sulphate, filtered, solvent was removed on vacuo yields a yellow oil 95% of the title compound **5**.

$C_{17}H_{33}N_1O_{10}$ (Mo. Wt. 411)

^{1}H-NMR ($CDCl_3$, 250 MH_Z): δ = 7.25 (broad s, 1H ; NH); 4.07 (s, 2H; CH_2CO); 3.90 (s, 2H, CH_2CONH); 3.40-3.70 (m, 22H; CH_2 of OEG-chain); 3.38 (t, 2H; CH_2NH); 3.25 (s, 3H; CH_3O).

IR (KBr) cm^{-1}: 3353 (OH stretching of COOH); 2918, 2875 (C-H stretching of CH_2CH_3); 1739 (C=O stretching of acid); 1669 (C=O stretching of amide); 1632 (N-H bending of amide); 1454 and 1350 (C-H bending of CH_2CH_3); 1279 (C-O stretching of acid); 1247 (C-O stretching of amide); 1119 (C-N stretching of amide).

MASS (FAB^+ in $CDCl_3$): $C_{17}H_{33}N_1O_{10}$ (Mo. Wt. 411): [m/z]: 412.1 $(M+H)^+$.

(2-{2-[2-(-2{-2[2-(2-Methoxy-ethoxy)-ethoxy-acetylamino}-ethoxy)-ethoxy]-ethoxy}-ethoxy)-acetyl chloride (6)

0.2 g of above acid **5** was dissolved in CH_2Cl_2 and under cooling with ice-bath 2 equivalent of oxalyl chloride added at 0 °C. After stirring at this temperature for 1h, the mixture was slowly brought to room temperature and stirred for overnight. The removal of solvent under low pressure affords product use such as for self-assembly.

Synthesis of TsOH.GGG-OCH$_2$Ph (7)

H_2N-GGG-OH (3.0 g, 15.9 mmol) and *p*-toluenesulfonic acid (monohydrate, 3.6 g, 18.9 mmol) were added to a mixture of benzyl alcohol (20 mL) and toluene (30 mL). The mixture was heated to reflux and water was removed by using a Dean-Stark trap. When no more water appeared in the distillate, heating was stopped. The mixture was cooled to room temperature, diluted with ether (50 mL) and cooled in an ice water bath for 2 h. Crystalline TsOH.GGG-OCH$_2$Ph was collected on a filter, washed with ether (50 mL) and dried. After recrystallization from methanol-ether (1:1), the salt **7** (5.5 g, 77%) melted at 176-177 ^{o}C.

^{1}H-NMR CDCl$_3$: 2.34 (3H, s, CH_3Ph), 3.74 (2H, s Gly NCH_2), 3.97 (4H, s, Gly NCH_2), 5.14 (2H, s, PhCH_2O), 7.21 (2H, d, *J* = 8.4 Hz, tosyl HAr); 7.30-7.35 (5H, m, Ph HAr), 7.69 (2H, d, *J* = 8.4, tosyl HAr).

^{13}C-NMR: 21.4, 41.7, 43.2, 68.1, 127.2, 129.5, 129.6, 130.2, 137.5, 142.1, 143.7, 168.4, 171.4, 172.2.

IR (KBr) : 3331, 3083, 1747, 1670, 1545, 1456, 1406, 1362, 1202, 1125, 1035, 1011, 913, 817, 736, 685 cm^{-1}.

***Anal.* Calcd for** $C_{20}H_{26}O_7N_3S$: C,53.21; H, 5.58; N, 9.31. Found: C, 53.18; H, 5.62; N, 9.37.

OEG-GGG-OCH$_2$Ph (8)

To OEG-carboxy (1.421 g, 7.9 mmol) dissolved in CH_2Cl_2 (40 mL), 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (1.51g, 7.9 mmol) was added and the mixture was stirred at room temperature. After 0.5 h, TsOH.GGG-OCH$_2$Ph (3 g, 6.6 mmol) and triehylamine (0.79 g, 7.9 mmol) were added and the mixture was stirred at ambient temperature overnight. The reaction mixture was successively washed with water (30 mL), 0.5 M HCl (30 mL), water (30 mL), 10% Na_2CO_3 (30 mL), and brine (20 mL), dried ($MgSO_4$), evaporated and the residue crystallized fro MeOH to offered a pure solid of OEG-GGG-OCH$_2$Ph **8** (86%).

1H-NMR CD_3OD: 3.25 (s, 3H; CH_3O); 3.40-3.81 (m, 8H; $\underline{CH_2}$ of OEG-chain); 3.90-4.05 (6H, m, Gly NCH_2), 4.07 (s, 2H; $\underline{CH_2}CO$); 5.14 (2H, s, $PhCH_2O$), 7.30-7.35 (5H, m, Ph HAr).

^{13}C-NMR : 49.0, 49.3, 49.6, 59.0, 67.9, 71.2, 71.3, 72.0, 72.8, 129.2, 129.3, 129.5, 137.2, 171.0, 171.9.
MASS (Xe, pos-FAB): $C_{20}H_{29}N_3O_8$ (439 g/Mol); [m/z]: 440.2 $[M+H]^+$, 463.1$[M+Na]^+$.

OEG-GGG-OH (9)

OEG-GGG-OCH_2Ph **8** (1g) was dissolved in absolute ethanol (100 mL) and 10% Pd/C (0.2 g) was added and the mixture was shaken under 60 psi H_2 for 3 h. The reaction mixture was heated to reflux and filtered hot through a celite pad. The solvent was evaporated under reduced pressure to offered white solid (95%).

1H-NMR CD_3OD: 3.25 (s, 3H; CH_3O); 3.40-3.81 (m, 8H; $\underline{CH_2}$ of OEG-chain); 3.90-4.05 (6H, m, Gly NCH_2), 4.1 (s, 2H; $\underline{CH_2}CO$);

^{13}C-NMR : 48.3, 48.6, 49.0, 59.0, 71.2, 71.4, 71.7, 72.0, 72.8, 171.1, 171.9, 172.7, 173.7.

MASS (Xe, pos-FAB): $C_{13}H_{23}N_3O_8$ (349 g/Mol); [m/z]: 350 $[M+H]^+$.
***Anal.* Calcd for** $C_{13}H_{23}N_3O_8$: C,44.7; H, 6.64; N, 12.03. Found: C, 44.18; H, 6.62; N, 12.0.

OEG-GGG-Cl (10)

0.2 g of above acid **9** was dissolved in CH_2Cl_2 and under cooling with ice-bath 2 equivalent of oxalyl chloride added at 0 °C. After stirring at this temperature for 1h, the mixture was slowly brought to room temperature and stirred for overnight. The removal of solvent under low pressure affords product **10** use such as for self-assembly.

Decanedioic acid monobenzyl ester (11)

Seboceic acid (4.04 g, 20 mmol) was reacted with a potassium hydroxide (20 mmol) solution in water (10 ml) stirring for 1 hour at room temperature. Enough toluene was added and the azeotrope was evaporated to dryness. 4.8 g (20 mmol) of potassium seboceate were obtained. 60 ml toluene were added and mixed with 0.6 g (2 mmol) TBAB (Tetrabutyl ammonium bromide) and 4.6 ml (20 mmol) of benzyl bromide. The reaction mixture was stirred at reflux temperature for 5 hours. Cool the mixture to room temperature and evaporation of solvent gave a white residue which was purified on silica gel column (Hexane/ Ethyl acetate 2:1) : yield 65% as a white shiny crystals of decanedioic acid monobenzyl ester **11**.

$C_{17}H_{24}O_4$ (Mo. Wt. 292)

^{1}H-NMR ($CDCl_3$, 500 MH_Z): δ = 7.29 (s, 5H, aromatic); 5.12 (s, 2H; benzyl proton); 2.35 (t, 4H; H^{α}); 1.65 (m, 4H, H^{β}); 1.3 (m, 8H).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 179.46, 173.55, 136.29, 128.49, 128.11, 66.05, 34.31, 33.94, 29.00, 28.94, 24.90, 24.63.

IR (KBr) cm^{-1}: 3447 (O-H stretching of acid); 3064 and 3033 (C-H stretching of aromatic); 2934, 2915, 2865 and 2849 (C-H stretching of CH_2CH_3); 1736 (C=O stretching of ester); 1700 (C=O stretching of acid); 1469, 1463, 1431 and 1387 (C-H bending of CH_2CH_3); 1411 (O-H in plane bending); 1301 (C-O stretching of acid); 1232 (C-O stretching of ester); 939 (O-H out of plane bending); 746 (C-H out of plane bending of aromatic).

MASS (Xe, pos-FAB in $CDCl_3$); $C_{17}H_{24}O_4$ (Mo. Wt. 292); [m/z]: 292.8 $(M+H)^+$, 314.9 ($M+Na^+)^+$, 90.9 $(C_7H_7)^+$.

9-(Methoxy carbonyl methyl carbamoyl) nonanoic acid benzyl ester (12)

2 g (6.8 mmol) of the decanedioic acid monobenzyl ester **11** was dissolved in 80 ml of dry chloroform, 1.38 g (13.68 mmol) triethylamine was added and cooled to –10 ^{o}C. The reaction mixture was stirred for half an hour at –10 ^{o}C. 1.484 g (13.68 mmol) ethyl chloroformate dissolved in 50 ml of ice cold dry chloroform was added dropwise of such a rate, that the temperature never reached –5 ^{o}C. The solution was stirred for 3 hours. Subsequently an ice cold solution of 0.84 g (6.8 mmol) glycine methyl ester hydrochloride in 100 ml ethanol/ triethylamine / water (70:25:5) was added. The resulting mixture was stirred for overnight with warming to room temperature. Removal of the solvent yielded a solid which was partitioned between water and chloroform. The organic phase was separated and dried with magnesium sulfate, filtered, and evaporation of solvent gave white residue which was purified on silica gel column (Methanol/ Chloroform 1:100): afforded of the title compound **12** as a white powder, 1.7 g; 85 %.

$C_{20}H_{29}N_1O_5$ (Mo. Wt. 363)

^{1}H-NMR ($CDCl_3$, 250 MH_Z): δ = 7.32 (s, 5H, aromatic); 5.98 (broad s, NH); 5.12 (s, 2H; benzyl proton); 3.95 (d, 2H; $\underline{CH_2}NHCO$); 3.68 (s, 3H; CH_3O); 2.29 (t, 2H; α-H of ester); 2.15 (t, 2H; α-H of amide); 1.55 (m, 4H, H^{β}); 1.2 (m, 8H).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 173.49, 173.21, 170.49, 136.04, 128.40, 128.00, 65.91, 52.10, 41.02, 36.14, 34.15, 28.98, 28.96, 28.88, 25.37, 24.76.

IR (KBr) cm^{-1}: 3363 and 3091 (N-H stretching. of amide asymmetric and symmetric respectively), 3034 (C-H stretching of phenyl), 2934 and 2854 (C-H stretching of CH_2CH_3), 1755 (C=O stretching of ester),1724 (C=O stretching of benzyl ester), 1662 (C=O stretching of amide), 1438 anmd 1375 (C-H bending of CH_2CH_3), 1207 and 1179 (C-O stretching of esters), 848, 780 (methylene rock),

MASS (EI, 115 ^{o}C); $C_{20}H_{29}N_1O_5$ (Mo. Wt. 363); 363 $(M)^+$, 91$(C_7H_7)^+$.

9-(Methoxy carbonylmethyl-carbamoyl) nonanoic acid (13)

9-(Methoxy carbonyl methyl carbamoyl) nonanoic acid benzyl ester **12** (1 g, 2.7 mmol) was dissolved in 20ml of dry THF: Methanol (3:1) solution. A 10% portion of Pd/C (10%) was added, and hydrogen was bubbled through the solution. Reaction was carried out at room temperature overnight. Pd/C was filtered off, solvent was removed in vaccuo to give the product **13** as a white solid; which was recrystallised from hexane:chloroform (5:2) yielded 0.87 g (87%).

$C_{13}H_{23}N_1O_5$ (Mo. Wt. 273)

^{1}H-NMR ($CDCl_3$, 250 MH_Z): δ = 6.31 (broad s, NH); 3.95 (d, 2H; $\underline{CH_2}NHCO$); 3.68 (s, 3H; CH_3O); 2.15 (t, 4H; H^{α}); 1.60 (m, 4H, H^{β}); 1.2 (m, 8H).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 177.25, 174.17, 170.55, 52.10, 42.39, 41.02, 36.09, 33.89, 28.93, 28.87, 28.83, 25.35, 24.72.

IR (KBr) cm^{-1}: 3377 (Free OH stretching of acid), 3320 and 3070 (N-H stretching of amide asymmetric and symmetric respectively), 2931 and 2852 (C-H stretching of CH_2CH_3), 1750, 1734 and 1642 (C=O stretching of acid, ester and amide respe.) 1437 and 1375 (C-H bending of CH_2CH_3), 1416 (O-H in plane bending),1240 and 1206 (C-O stretching), 923 (O-H out of plane bending). 729.

MASS (EI, 115 ^oC); $C_{13}H_{23}N_1O_5$ (Mo. Wt. 273): 273.8 $(M+H)^+$.

ElementalAnalysis: $C_{13}H_{23}N_1O_5$ (Mo. Wt. 273)

Calculated: 57.14 % C, 8.42 % H, 5.12 % N

Found : 56.83 % C, 8.05 % H, 5.00 %N

(9- Chlorocarbonyl nonanoylamino)-acetic acid methyl ester (14)

0.5 g of above acid **13** was dissolved in CH_2Cl_2 and under cooling with ice-bath 2 equivalent of oxalyl chloride added at 0 °C. After stirring at this temperature for 1h, the mixture was slowly brought to room temperature and stirred for overnight. The removal of solvent under low pressure affords product use such as for self-assembly.

9-(3-Bromo propylcarbamoyl) nonanoic acid benzyl ester (18)

2 g (6.8 mmol) of the decanedioic acid monobenzyl ester **11** was dissolved in 80 ml of dry chloroform, 1.38 g (13.68 mmol) triethylamine was added and cooled to –10 ^{o}C. The reaction mixture was stirred for 0.5 hour at –10 ^{o}C. 1.484 g (13.68 mmol) ethyl chloroformate dissolved in 50 ml of ice cold dry chloroform was added dropwise of such a rate, that the temperature never reached –5 ^{o}C. The solution was stirred for 3 hours. Subsequently an ice cold solution of 1.499 g (6.8 mmol) of 3-bromo-1-propylamin hydrobromide in 100 ml ethanol / triethylamine / water (70:25:5) was added. The resulting mixture was stirred for overnight with warming to room temperature. Removal of the solvent yielded solid which was partitioned between water and chloroform. The organic phase was separated and dried with magnesium sulfate, filtered and evaporation of solvent gave white residue which was purified on silica gel column (Methanol/ Chloroform 0.1:10) yields 85% of title compound **15**.

$C_{20}H_{30}N_1O_3$ (Mo. Wt. 411)

^{1}H-NMR ($CDCl_3$, 500 MH_Z): δ 7.24 (s, 5H, aromatic); 5.12 (s, 2H; benzyl proton); 4.95 (broad s, NH); 4.12 (t, 2H; $\underline{CH_2}Br$), 3.30 (t, 2H; $\underline{CH_2}NH$); 2.31 (m, 4H; Hα); 1.89 (m, 2H); 1.50 (m, 4H, H^{β}); 1.2 (m, 8H).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 178.00, 173.21, 128,42, 128.01, 66.11, 60.72, 53.65, 39.21, 32.51, 30.56, 29.17, 28.91, 24.86, 14.51.

MASS (EI, 115 ^{o}C); $C_{20}H_{30}N_1O_3$ (Mo. Wt. 411); [m/z]: 412 $(M+H)^+$, 332 $(M-Br)^+$, 90.9 $(C_7H_7)^+$

ElementalAnalysis: $C_{20}H_{30}N_1O_3$ (Mo. Wt. 411);

Calculated: 58.39 % C, 7.29 % H, 3.40 % N

Found : 58.80 % C, 7.58% H, 4.86 % N

[3-(9-Benzyloxycarbonyl nonanoylamino) propyl] trimethyl ammonium bromide (16)

Dissolve 9-(3-Bromo propylcarbamoyl) nonanoic acid benzyl ester **15** (1 g) in 15 ml of methanol and added excess ammount of trimethylamine (30 % in water), reflux mixture for 3 hours. Cool to room temperature and evaporated solvent in reduced pressure coevaported with methanol, followed by washing with hexane, chloroform and dry under vaccum to offord white solid as title compound **16,** yield 85 %.

^{1}H-NMR ($CDCl_3$, 500 MH_Z): δ= 7.25 (s, 5H, aromatic); 7.21(broad s, 1H, NH); 5.12 (s, 2H; benzyl proton); 3.50 (t, 2H; $\underline{CH_2}N^+(CH_3)_3$), 3.30 (s, 9H, $(\underline{CH_3})_3N^+$); 3.25 (t, 2H; $\underline{CH_2}NH$); 2.25 (t, 2H; H^α); 2.15 (t, 2H; H^α); 1.78 (m, 2H); 1.52 (m, 4H, H^β); 1.23 (m, 8H).

ElementalAnalysis: $C_{23}H_{39}N_2O_3\,Br_1$ (Mo. Wt. 470);

Calculated: 58.72 % C, 8.29 % H, 5.95 % N
Found : 58.87 % C, 8.79 % H, 5.39 % N

[3-(9- carboxy nonanoylamino) propyl] trimethyl ammonium bromide (17)

0.85 g of [3-(9-Benzyloxycarbonyl nonanoylamino) propyl] trimethyl ammonium bromide **16** from the above reaction was dissolved in 15ml of dry THF: Methanol (3:1) solution. A 10% portion of Pd/C (10%) was added, and hydrogen was bubbled through the solution. Reaction was carried out at room temperature overnight. Pd/C was filtered off, solvent was removed in vaccuo to give the product **17** as a white solid; which was recrystallised from Hexane: Chloroform (5:2): yield 85%.

^{1}H-NMR ($CDCl_3$, 500 MH_Z): δ= 7.10 (broad s, NH); 3.50 (t, 2H; $\underline{CH_2}N^+(CH_3)_3$), 3.30 (s, 9H, $(\underline{CH_3})_3N^+$); 3.00 (t, 2H; $\underline{CH_2}NH$); 2.25 (m, 4H; H^{α}), 1.98 (m, 2H); 1.60 (m, 4H, H^{β}); 1.35 (m, 8H).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 178.12, 168.00, 65.65, 49.69, 47.99, 38.65, 34.75, 31.51, 30.05, 25.88, 24.75, 15.00.

[3-(9-Chlorocarbonyl-nonanoylamino)-propyl]-trimethyl ammonium bromide (18)

0.5 g of above acid **17** was dissolved in CH_2Cl_2 and under cooling with ice-bath 2 equivalent of oxalyl chloride added at 0 °C. After stirring at this temperature for 1h, the mixture was slowly brought to room temperature and stirred for overnight. The removal of solvent under low pressure affords product **18** use such as for self-assembly.

Synthesis of 1.5 nm bolaamphiphile (27)

16-Hydroxy-hexadecanoic acid benzyl ester (19)

A solution of 16-hydroxydodecanoate acid (5g, 0.018 mol) in 140 ml DMF was treated with potassium bicarbonate (3.65g, 0.036mol) and benzyl bromide (6.25g, 0.036mol) were added drop wise, stirred reaction mixture for 24h at ambient temperature. The solvent was removed under reduced pressure. The resulting mixture was partitioned between ethyl acetate and aqueous HCl. The organic phase was separated, washed with water and dried with $MgSO_4$. Removal of the solvent in vacuo resulted in a solid, which was recrystallized in methanol to afford white crystals: yield 5.8 g (86 %) of **19**.

$C_{23}H_{38}O_3$ (Mo. Wt. 362)

^{1}H NMR (500 MHz, $CDCl_3$): δ= 7.35 (s, 5H, aromatic); 5.11 (s, 2H, $\underline{CH_2}$Ph); 3.63 (t, 2H, $\underline{CH_2}$OH); 2.32 (t, 2H, $\underline{CH_2}$COO); 1.61 (m, 8H, 4×CH_2); 1.32 (m, 18H, 9×$\underline{CH_2}$),

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 173.12, 128.52, 128.12, 66.03, 63.08, 29.61, 29.59, 29.55, 29.42, 29.22

IR (KBr) cm^{-1}: 3322 (O-H stretching of primary alcohol), 2915 and2848 (C-H stretching of methylene), 1735 (C=O stretching of ester), 1471 (C=C ring stretching of aromatic), 1415 and 1390 (C-H bending of methylene), 1171 (C-O stretching of ester), 1062 (C-O stretching of primary alcohol), 717 (methylene rock).

MASS (EI, 115 ^oC); $C_{23}H_{38}O_3$ (Mo. Wt. 362); [m/z]: 362 $(M)^+$.

16-Oxo-hexydecanoic acid benzyl ester (20)

Pyridinium chlorochromate (4.46g, 20mmol) was suspended in 120ml CH_2Cl_2 and the 16-hydroxy-hexadecanoic acid benzyl ester **19** (5g, 13mmol) was rapidly added at room temperature. After 1.5 hours the oxidation was completed (monitored by TLC). The black reaction mixture was diluted with 300 ml of anhydrous ether, the solvent was decanted, and the black solid was washed twice with ether. The product was isolated simply by filtration of the organic extracts through florisil and evaporation of the solvent at reduced pressure affords the product **20** : yielded 4.5g (91.8%) as an oil.

$C_{23}H_{36}O_3$ (Mo. Wt. 360)

^{1}H NMR (500 MHz, $CDCl_3$): δ= 9.71 (s, 1H, CHO); 7.30 (s, 5H, aromatic); 5.05 (s, 2H, CH_2Ph); 2.35 (t, 2H, CH2COH); 2.25 (t, 2H, CH_2COO); 1.65 (m, 6H, 3×CH_2); 1.20 (m, 18H, 9×CH_2),

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 202.91, 172.50, 128.53, 128.14, 66.04, 34.33, 29.59, 29.55, 29.33, 29.23, 29.16, 29.12, 24.95.

IR (KBr) cm^{-1}: 3406 (overtone of C=O stretching), 3064 and 3035 (C-H stretching of aromatic), 2916 and 2848 (C-H stretching of methylene), 1735 (C=O stretching of ester), 1713 (C=O stretching of aldehyde), 1472 (C=C ring stretching of aromatic), 1413 and 1390 (C-H bending of methylene), 1239 (C-O stretching of ester), 747(methylene rock).

MASS (EI, 100°C); $C_{23}H_{36}O_3$ (Mo. Wt. 360); [m/z] : 360 $(M)^+$.

ElementalAnalysis: $C_{23}H_{36}O_3$ (Mo. Wt. 360):

Calculated: 76.66 % C, 10.00 % H,

Found : 76.05 % C, 9.76 % H,

Octadec-2-enedioic acid 18-benzyl ester 1-*tert*-butyl ester (21)

0.09 g (3.75 mmole) Sodium hydride was suspended in THF (30mL) at 0°C under the argon atmosphere. 0.93g (4.1mmole) *tert*-butyl P,P-dimethylphosphono acetate was added drop wise at this temperature; after the evolution of H_2 bubbles had ceased (0.5h), a solution of 16-oxo-hexydecanoic acid benzyl ester 1.5g (4.1mmole) **20** in 10 ml THF was added slowly. The resulting reaction mixture was stirred for 24 hours. The solvent was removed under reduced pressure and the residue taken up with water. After extraction with four portions of ether and subsequently drying, a white solid was obtained. This was re-crystallized from hexane to give 1.4 g product **21** (74%).

$C_{29}H_{46}O_4$ (Mo. Wt. 458)

^{1}H NMR (500 MHz, $CDCl_3$): δ= 7.35 (s, 5H, aromatic.); 6.90 (dd, 1H, J_1=11, J_2= 3Hz, vinyl β-H); 5.70 (d, 1H, vinyl α-H, J = 11 Hz, vinyl α-H); 5.10 (s, 2H, $\underline{CH_2}$Ph); 4.15 (2H, t); 2.32 (m, 4H, 2xCH_2), 1.61 (m, 4H, 2xCH_2), 1.47 (s, 9H, $(\underline{CH_3})_3$C), 1.25 (m, 18H, 9xCH_2),

^{13}C NMR (63 MHz, $CDCl_3$): δ = 172.50, 163.10, 148.15, 128.50, 128.12, 122.89, 66.01, 34.32, 29.60, 29.22, 28.15, 24.93.

MASS (Xe, pos- FAB, $CDCl_3$); $C_{29}H_{46}O_4$ (Mo. Wt. 458); [m/z]: 458.9 $(M+H)^+$.

ElementalAnalysis: $C_{29}H_{46}O_4$ (Mo. Wt. 458):

Calculated: 75.98 % C, 10.04 % H,
Found : 75.53 % C, 9.99 % H,

Octadec-2enedioic acid 18-benzyl ester (22)

A 30 ml toluene solution containing 1.4g of the Octadec-2-enedioic acid 18-benzyl ester 1-*tert*-butyl ester **21** and 0.1 g *p*-toluenesulfonic acid (PTSA) were refluxed for 30 min, and subsequently stirred at room temperature overnight. After removing toluene, 60ml of 5% aqueous potassium bicarbonate solution was added and stirred for 10 minutes. The white precipitate was filtered off and the filtrate was acidified to pH 3 with dilute HCl. The resulting suspension was extracted with chloroform and dried with magnesium sulphate. After the removal of solvent in vacuum, the resulting solid was recrystallized from chloroform/hexane obtained 1.18g (96%) white powder of octadec-2enedioic acid 18-benzyl ester **22**.

$C_{25}H_{38}O_4$ (Mo. Wt. 402)

^{1}H NMR (250MHz, $CDCl_3$): δ: 7.41 (s, 5H, aromatic.); 6.91 (dd, 1H, vinyl β-H); 5.72 (d, 1H, vinyl α-H); 5.05 (s, 2H, CH_2Ph); 2.41 (t, 2H, CH_2COO); 2.26 (m, 2H, CH_2); 1.65 (m, 2H, CH_2); 1.46 (m, 2H, CH_2), 1.22 (m, 20H, 10xCH_2),

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 179.00, 172.50, 152.3, 128.51, 128.12, 125.29, 66.03, 34.35, 32.28, 29.58, 29.48, 29.42, 29.34, 29.22, 29.12, 27.89, 24.96.

MASS (Xe, pos-FAB); $C_{25}H_{38}O_4$ (Mo. Wt. 402) m/z : 402 $(M)^+$

1-[2-(2-Azido-ethoxy)-ethoxy]-2-methoxy-ethane (23)

2-[-(2-Metoxy-ethoxy) ethoxy] ethanol (10mmol) was treated with triethylamine (15 mmol) followed by methanesulfonyl chloride (10 mmol) in dichloromethane (40 mL). The reaction mixture was stirred for 1hr at room temperature, filtered, solvent was removed on rotavapour, afford methanesulfonic acid-2-[2-(2-methoxy ethoxy) ethoxy] ethyl ester.

The residual mesylated product was dissolved in 50 mL ethanol and treated with sodium azide (1.5 eq.) at reflux temp. for 4hrs. H_2O (20mL) was added and mixture extracted with CH_2Cl_2. After drying and evaporation, the residue was chromatographed (AcOEt). Yielded 92% of azide **23**.

^{1}H NMR (250 MHz $CDCl_3$): δ = 3.49 (t, 2H, CH_2O), 3.35 (s, 3H, CH_3O), 3.3 (t, 2H, CH_2N_3), 3.5-3.6 (m, 8H, OCH_2CH_2O).

2-[-2-(2-Metoxy-ethoxy) ethoxy] ethylamine (24)

At room temperature, 1-[2-(2-azido-ethoxy) ethoxy]-2-methoxy ethane **23** (4mmol), triphenyl phosphine (Ph_3P) in dry THF (20mL) was stirred for 4 hrs. Then treated with water (1mL), stirred overnight. The solution was directly evaporated and the residue was column chromatograph obtained **24** as an slightly yellow oil 99%.

$C_7H_{17}N_1O_3$ (Mo. Wt. 163)

^{1}H NMR (250 MHz $CDCl_3$): δ = 3.48 (t, 2H, CH_2O), 3.3 (s, 3H, CH_3O), 3.2 (t, 2H, CH_2NH_2), 3.5-3.7 (m, 8H, OCH_2CH_2O).

MASS (EI, 100^{o}C); $C_7H_{17}N_1O_3$ (Mo. Wt.163): [m/z] : 164.4$(M+H)^+$.

17-{2-[2-(2-Methoxy ethoxy) ethoxy] ethylcarbamoyl} heptadec-16-enoic acid benzyl ester (25)

0.32g (1.9 mmol) 2-[2-(2-methoxy-ethoxy) ethoxy] ethylamine **24** and 0.8 g (1.9 mmol) octadec-2-enedioic acid 18-benzyl ester **22** were dissolved in 50 ml of CH_2Cl_2. After cooling at 0 °C for 15 min, 0.62 g (1.5 eq.) DCC and 0.1g (catalytic) DMAP were added. The reaction mixture was then stirred at room temperature for further 24 hours. The white precipitate was filtered off and the filtrate washed successively with 0.1 M HCl, 8% $NaHCO_3$, water, and dried over $MgSO_4$. The solvent was removed in vacuum and the residue purified by silica column (CH_2Cl_2: MeOH 9:1), Yield: 0.9g (90%) of **25** white solid was obtained.

$C_{32}H_{53}N_1O_6$ (Mo. Wt.547)

^{1}H NMR (250 MHz $CDCl_3$): δ= 7.35 (s, 5H, aromatic.); 6.80 (dd, 1H, vinyl β-H); 6.45 (broad s, 1H, NH); 5.72 (d, 1H, vinyl α-H); 5.05 (s, 2H, CH_2Ph); 3.58-3.7 (m, 10H, CH_2O), 3.57 (m, 2H, CH_2NH); 3.30 (s, 3H, CH_3-O); 2.39 (t, 2H, $\underline{CH_2}COO$); 1.81 (m, 2H, allyl-H); 1.51 (m, 4H, CH_2), 1.25 (m, 20H, 10xCH_2).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 171.27, 165.87, 144.20, 131.71, 128.22, 127.83, 123.43, 71.66, 70.23, 70.17, 69.87, 69.58, 65.70, 58.65, 55.40, 34.65, 33.74, 30.58, 29.34, 29.16, 28.95, 28.46, 28.00, 27.75, 25.49, 25.19, 24.67, 24.38, 20.68,

Mass (Xe, Pos-FAB); $C_{32}H_{53}N_1O_6$ (Mo. Wt.547); m/z: 548 $[M+H]^+$.

17-{2-[2-(2-Methoxy-ethoxy) ethoxy] ethyl carbamoyl} heptydec-16-enoic acid (26)

17-{2-[2-(2-Methoxy-ethoxy) ethoxy] ethylcarbamoyl}heptadec-16-enoicacid benzyl ester **25** (0.9 g) was treated with 18 ml of LiOH (1M) suspension in 10 ml of THF : methanol:water (6:2:2). The resulting mixture was stirred overnight at room temperature. After removal of the solvent in vacuum, the mixture was extracted with ethyl acetate and water. The aqueous phases were combined and acidified to pH 2 with dilute HCl. The suspension was extracted with chloroform, dried with $MgSO_4$ and evaporated to afford **26** (0.72g, 94%) as a white solid.

$C_{25}H_{47}N_1O_6$ (Mo. Wt.457)

^{1}H NMR (250 MHz $CDCl_3$): δ= 6.80 (dd, 1H, vinyl β-H); 6.45 (broad s, 1H, NH); 5.72 (d, 1H, vinyl α-H); 3.58-3.7 (m, 10H, CH_2O), 3.57 (m, 2H, CH_2NH); 3.30 (s, 3H, CH_3-O); 2.39 (t, 2H, $\underline{CH_2}COO$); 1.81 (m, 2H, allyl-H); 1.51 (m, 4H, CH_2), 1.25 (m, 20H, 10xCH_2).

^{13}C NMR ($CDCl_3$, 125 MHz): δ= 177.62, 166.41, 144.96, 123.34, 71.75, 70.32, 70.24, 69.97, 69.74, 64.87, 58.86, 49.03, 39.11, 33.95, 33.61, 31.91, 29.41, 29.25, 29.08, 28.97, 28.14, 25.46, 24.71

Mass (Xe, Pos-FAB); $C_{25}H_{47}N_1O_6$ (Mo. Wt. 457); m/z: 457.9 $(M+H)^+$.

17-{2-[2-(2-Methoxy-ethoxy) ethoxy] ethyl carbamoyl} heptydec-16-enoyl chloride (27)

0.2 g of above acid **26** was dissolved in CH_2Cl_2 and under cooling with ice-bath 2 equivalent of oxalyl chloride added at 0 °C. After stirring at this temperature for 1h, the mixture was slowly brought to room temperature and stirred for overnight. The removal of solvent under low pressure affords product use such as for self-assembly.

3-Ethoxycarbonylpropyl-2,4-pentanedione (28)

To a solution of the anhydrous potassium carbonate (40 g, 0.29 mol) in dry DMF (100ml) at 90 ^{o}C was added acetylacetone (30 g, 0.29 mol) and ethyl 4-bromo butyrate (58.43 g, 0.29 mol) slowly. The mixture was stirred and heated further 6 hrs. and then poured into 500 ml of water. The solution was then extracted by using dichloromethane. The extract was then washed with water and distilled under vacuum at 150-157 ^{o}C and 15-17 mbar. Obtained yield of title compound 3-ethoxy carbonylpropyl-2,4-pentanedione **28** was 65%.

TLC (Etylacetate / Hexane 1:9) R_f = 0.4

$C_{11}H_{18}O_4$ (Mo. Wt.214)

^{1}H-NMR ($CDCl_3$, 500 MH_Z): δ = 4.10 (q, 2H); 3.50 (t, 1H); 2.42 (t, 2H); 2.10 (s, 6H); 1.91 (m, 2H); 1.75 (m, 2H); 1.18 (t, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 203.00, 172.71, 67.89, 59.92, 33.35, 23.57, 22.31, 19.17, 13.70,

IR (KBr) cm^{-1}: 3445 and 3349 (Overtone of C=O stretching), 2981 and 2874 (C-H stretching of CH_2CH_3), 1733 (C=O stretching of ester), 1700 and 1681 (C=O stretching of ketone), 1421 and 1374 (C-H bending of CH_2CH_3), 1272 (C-O stretching of ester), 636 (methylene rock).

MASS (Xe, pos-FAB in $CDCl_3$); $C_{11}H_{18}O_4$ (Mo. Wt. 214);

[m/z]: 215 $(M+H)^+$, 115 ($M-C_5H_7O_2)^+$.

2,4-Dimethyl-3-ethoxycarbonylpropyl-5-benzyloxycarbonyl pyrrole (29)

To a stirring solution of benzylacetoacetate (30.9 g, 0.16 mol) dissolved in acetic acid (60 ml) at 30 ^{o}C was added a solution of sodium nitrite (11.095 g, 0.16 mol) in water (20 ml). The solution was stirred for 1 hour and added slowly to (25.87 g, 0.16 mol) of 3-ethoxycarbonylpropyl-2,4-pentanedione **28** in 60 ml of acetic acid with the simultaneous addition of 29 g of zinc dust (temperature of reaction mixture not higher than 70 ^{o}C). The reaction mixture was heated on water bath for 1 hour, cooled and diluted with 100 ml of water. The pyrrole that separated was filtered off, dried and purified by silica gel column (ethylacetate/hexane 2.5:7.5): yield was 58 % of 2,4-dimethyl-3-ethoxycarbonylpropyl-5-benzyloxycarbonyl pyrrole **29**.

$C_{20}H_{25}N_1O_4$ (Mo. Wt. 343)

^{1}H-NMR ($CDCl_3$, 500 MH_Z): δ = 8.50 (broad s, 1H); 7.48 (s, 5H; aromatic); 5.21 (s, 2H; benzyl); 4.12 (q, 2H); 2.40 (t, 2H); 2.25 (m, 2H); 2.19 and 2.23 (s, 6H, 2×CH_3); 1.75 (t, 2H); 1.18 (t, 3H).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 173.49, 161.40, 136.56, 130.36, 128.37, 128.33, 127.98, 120.99, 116.39, 65.27, 60.31, 33.69, 28.86, 23.14, 14.10, 11.27, 10.62

MASS (Xe, pos-FAB in $CDCl_3$); $C_{20}H_{25}N_1O_4$ (Mo. Wt. 343); [m/z]: 344 $(M+H)^+$, 342.8 $(M)^+$.

5,5'-Dibenzyloxycarbonyl-3,3'-di(3-etaxoycarbonylpropyl)-4,4'-dimethyl-2,2'-dihydrodipyrrin (30)

To a stirring solution of 2,4-dimethyl-3-ethoxycarbonylpropyl-5-benzyloxycarbonyl pyrrole , **29** (2 g, 5 mmol) in dry diethyl ether was added bromine (0.93 g, 5 mmol) over 30 minutes. The mixture was stirred for further 2 hours and the ether was evaporated on rotavap at room temperature. The precipitate was dissolved in 100 ml of ethanol, 1 ml of HBr acid was added and the mixture was boiled for 1 hour. The mixture was poured into 100 ml of water and left overnight. The precipitate was filtered off and purified on silica gel column (ethylacetate / hexane 1:9): to offord the title compound **30** (1.9 g, 95 %).

$C_{39}H_{46}N_2O_8$ (Mo. Wt. 670)

^{1}H-NMR ($CDCl_3$, 500 MH_Z): δ = 9.15 (s, 2H, NH); 7.28 (s, 10H, aromatic); 5.24 (s, 4H, Benzyl); 4.15 (q, 4H, CH_2 of ester); 3.78 (s, 2H, bridged methylene); 2.4 (t, 4H, CH_2CO); 2.25 (m, 4H); 2.00 (s, 6H, Methyl); 1.75 (t, 4H); 1.20 (t, 6H).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 179.26, 172.89, 135.34, 130.13, 128.40, 128.20, 128.14, 124.19, 66.41, 60.19, 60.09, 33.37, 33.14, 26.18, 25.54, 22.44, 13.99, 13.96, 9.67.

MASS (Xe, pos-FAB in $CDCl_3$); $C_{39}H_{46}N_2O_8$ (Mo. Wt. 670); [m/z]: 693 $(M+Na)^+$, 579 $(M-C_7H_7)^+$.

ElementalAnalysis: $C_{39}H_{46}N_2O_8$ (Mo. Wt. 670);

Calculated: 69.85 % C, 6.86 % H, 4.17 % N
Found : 69.48 % C, 7.07 % H, 3.42 % N

4,8,12,18-tetrakis[(3-ethoxycarbonyl-propyl)-3,7,13,17-tetramethyl-22,24-dihydro-porphin 2-yl]-butyric acid ethyl ester (31)

Palladium-on-carbon (10%; 200mg) was added to a solution of 5,5'-dibenzyloxy carb onyl-3,3'-di (3-etaxoycarbonylpropyl)-4,4'-dimethyl-2,2**'-**dihydrodi-pyrrin **30** (2.5 g, 3.7 mmol) in THF (100 cm^3) containing 1% triethylamine and the mixture was stirred under hydrogen for 1 h, by which time ca. 200 cm^3 (8 mmol) of gas had been consumed. The catalyst was filtered off and the solution of **30a** was evaporated. TFA (argon-saturated; 25 cm^3) was added under argon at 0 ^oC to generate a solution decarboxylated dipyrrole, after 20 min a solution of trimetoxy methane (0.395g, 3.7 mmol) in dichloromethane (argon-saturated; 100 cm^3) was added in to the mixture after which it was stirred for a further 2 hours. Triethylamine (20 cm^3) was then added to the mixture and the solvent removed by evaporation. The residue was treated with DDQ, yielded and was purified by flash chromatography on silica gel ($CHCl_3$; R_f: 0.2) followed by recrystallisation gives the title porphyrin **31**.

^{1}H-NMR ($CDCl_3$, 500 MH_Z): δ = 10.25 (s, 2H), 10.20 (s, 2H), 4.10 (q, 8H), 2.85 (m, 8H), 2.19 (m, 8H), 1.45 (m, 8H), 1.41(s, 12H), 0.95 (t, 12H), -3.7 (broad s, NH).

^{13}C NMR ($CDCl_3$, 125 MHz): δ = 173.70, 139.56, 96.82, 96,55, 60.27, 34.02, 28.05, 25.76, 14.25, 11.69.

MASS (Xe, pos-FAB); $C_{48}H_{62}N_4O_8$ (Mo. Wt**.** 822); [m/z]: 823 $(M+H)^+$.

Synthesis of fluoresceintriglycine tag (43)[113]

Triglycine (25 mg, 1 eq) was dissolved in a mixture of dry pyridine:DMF (1:1, 2 mL). To this solution was added FITC (1.5 eq) and the contents were stirred at room temperature under nitrogen and in darkness for 48 hrs. The solution was evaporated to dryness under vacuum at 20^{o}C and the residual material was washed with successively with diethyl ether (2×5 mL). The crude mixture was purified by preparative TLC on silica gel (EtOAC/CH_2Cl_2 ;1:5; R_f =0.4) to give the product **43** as a bright yellow solid (70%).

$C_{27}H_{22}N_4O_9S_1$ (Mo. Wt. 578)

^{1}H NMR (CD_3OD): δ 8.18 (d, 2H, J = 8.0, ArH); 7.91 (m, 2H, ArH); 7.64 (d, 2H, J = 8.0, ArH); 6.52-6.71 (m, 4H, ArH; NH), 4.14 (s, 2H, COOH$\underline{CH_2}$NH); 3.99 (s, 2H); 3.65 (s, 2H).

MASS (Xe, pos-FAB); $C_{27}H_{22}N_4O_9S_1$ (Mo. Wt. 578): 579.1 [M+H].

Synthesis of bolaamphiphile (Ketone Bola).

4-oxo-heptanedioic acid (48).

A 5 g (21.7 mmol) amount of 4-oxoheptandiacid diethyl ester was dissolved in 20 mL methanol, and the solution of 2 M methanolic KOH was added to it. After the addition the mixture was refluxed at 85 ^{o}C for 4 hrs. Then, the reaction mixture was cooled to room temperature, the solvent was removed at reduced pressure. A 100 mL volume of water was added. The mixture was acidified to pH 2 with dilute HCl. The suspension was extracted with ethylacetate followed by chloroform, dried with $MgSO_4$ and evaporated to afford **48** (3.5 g, 92 %) as a white solid.

^{1}H NMR (CD_3OD): δ 2.72 (t, 4H); 2.51 (t, 4H).

6-{2-[2-(2-methoxy-ethoxy)-ethoxy]-ethylcarbamoyl}-4-oxo-hexanoic acid (49).

A 3 g (17.2 mmol) amount of 4-oxo-heptanedioic acid **48** and 2-[2-(2-methoxy-ethoxy)-ethoxy]-ethylamine 0.93 g (5.7 mmol) were dissolved in 40 mL of dry THF. After cooling at 0 ^{o}C for 15 min, 1.9 g (17.2 mmol) of NHS was added and stirred reaction mixture for 30 min. At the same temperature 3.51 g (17.2 mmol) of DCC was added. The reaction mixture was then stirred at room temperature for further 24 hrs. The white precipitate was filtered off. The solvent was removed under reduced pressure, added ethyl acetate to remove residual DHU (repeated three times). Then the crude product was purified by silica column chromatography using eluent CH_2Cl_2:MeOH (8:2), yielding 1.65 g (90 %) of **49**.

^{1}H NMR ($CDCl_3$): δ 7.7 (broad s, 1H, NH); 3.52-3.71 (m, 10H, CH_2O); 3.35 (t, 2H, CH_2NH); 3.25 (s, 3H, CH_3O); 2.72 (t, 4H); 2.51 (t, 4H).

MS (FAB^+): m/z = 320 (M+H); (FAB^-): m/z = 319.3 $[M]^{\cdot -}$.

6-{2-[2-(2-methoxy-ethoxy)-ethoxy]-ethylcarbamoyl}-4-oxo-hexanoic chloride (50): 0.2 g of above acid **49** was dissolved in dichloromethane and under cooling with ice-bath at 0 ^{o}C at this temperature 2 equivalent of oxalyl chloride was added. After stirring at this temperature for 1 h, the mixture was slowly brought to room temperature and stirred for overnight. The removal of solvent under low pressure afford product **50**, used such as for self assembly.

7.2 Instruments:

Nuclear magnetic resonance spectra (NMR): The spectra were taken up with the spectrometer Bruker AC 250. The values of the chemical shift δ (ppm) refer to Tetramethylsilan (TMS).

Mass spectra (ms): The measurements took place at the devices CF 5 DF or MAT 711. Used kinds of ionization were the electron collision ionization (EGG) and the atomic impact ionization (FAB) with positive and negatively charged ions.

Elementary analyses (I/O): The regulations were undertaken with burn devices of the company Perkin Perkin-Elmer working by gas chromatography.

UV/vis spectra measurements

The porphyrin on the aminated silica particles were also characterized after each self-assembly process with electronic measured with a fiber optic LAMBDA of 16 spectrometers of the company Perkin-Elmer using of quartz cuvettes.

Fluorescence Experiments.

Fluorescence measurements and quenching experiments were performed on a Perkin-Elmer spectrometer (LS50B). The porphyrins on the covered silica particles were characterized after each self-assembly process with fluorescence as well as UV/vis spectrometer.

Transmission Electron Microscopy (TEM)

TEM samples were prepared by dropping 10 µl aliquots of colloidal solution (ethanol/H_2O 1:1) onto a carbon-coated grid. After about 1 min, the remaining solution was blotted off with a filter paper. A Philips M12 transmission electron microscope operated at 100 kV was used to obtain the images. The measurements were accomplished with a Philips's 12 cm. The sample preparation took place on copper nets with 3 mm diameter and 400 meshes (type B 8010 Cu, Blazer union)

7.3 Preparation of aminated silica particles

The silicate particles developed by van Blaaderen, are produced by hydrolysis of tetra ethoxysilane (TEOS) with aqueous ammonia in ethanol and are stabilized by subsequent treatment with (3-aminopropyl)-triethoxysilane.

Colloidal silica nanoparticles with a mean diameter of 100 nm were prepared according to the following procedure; All glass reaction vessels were cleaned extensively to ensure that no nucleation sites were present (washing procedure: filling with 3% hydrofluoric acid for an hour, rinsing with milli-Q water and finally rinsing with distilled ethanol). In a reaction vessel, which had been dried for 3 h at 120 °C, TEOS (1.5 mL) and ammonium hydroxide (3 mL, 28%) were dissolved in 50 mL of anhydrous ethanol, and the reaction mixture was slowly stirred at room temperature for 24 h in the dark. milli-Q water (400 µl) was added and the mixture was stirred for another 2 h further. Then, (3-aminopropyl) triethoxy silane (APTS) (400 µl) was added, and the mixture was stirred overnight in dark. The resulting silica particle was warmed to 80 °C and refluxed at this temperature for 10 h under an argon atmosphere. The amino-modified silica particles with a diameter of 100 nm were then used further for self-assembling work after cooling to room temperature. Unreacted (3-Aminopropyl)-triethoxysilane (APTS) was removed by repeated washing with anhydrous ethanol followed by dry DCM (each one three times) collected particles by centrifugation.

The surface of the particles could be coated through a subsequent chemical reaction with the silane coupling agent (3-aminopropyl)-triethoxysilane (APS). APS then forms a propyl amine coating on the silica particles which stabilizes them against water and organic solvents and render the surface reactive forward with acid derivatives. The qualitative reaction of APS on the silica spheres proved to be a very simple test to the presence of amino groups on the surface. If the silica particle was colored yellow in solution, the amine groups could always also be detected on dried silica. We used the amino modified silica colloidal particles for preparation of 2 nm gaps. In such studies was required to use stable, monodisperse, unclustered colloids

and also important to be able to adjust the surface properties and chemical composition of the particles.

Spherical particles with a diameter between 20 nm and 150 nm were obtained depending on concentration and hydrolysis time. The smaller 20 nm particles showed was obtained when hydrolysis time was 2 hrs., however, a rough surface in transmission electron microscopy (TEM) which was not appropriate for the self-assembly of rigid membranes and defined nanometer gaps. The smallest uniform particles with a perfectly smooth surface had a uniform diameter of 100 ± 10 nm. The measurements were accomplished with a Philips 12 mm electron microscopy. The sample preparation took place on copper nets with 3 mm diameter and 400 meshes (type B 8010 Cu, Blazer union). These particles were stable and could be stored indefinitely as a moist powder. When resuspended in milli-Q water at pH 7-8, transmission electron microscopy (TEM) always showed observed ill-defined networks of 100-nm spheres with a smooth surface.

Preparation of closed monolayer (yoctowell) on silica particles

The above 100 nm aminated silica colloid (0.5 g) was washed 4 times with anhydrous ethanol and dry CH_2Cl_2 by repeated centrifugation, dispersion, and ultrasonification. Then, obtained silica particles were dissolved in 50 mL of CH_2Cl_2 containing 1 mL of dry triethylamine. With vigorous stirring, 4 mL of CH_2Cl_2 solution of meta-tetracarboxy with ethylchloroformate activated meta-tetracarboxy porphyrin **32b** (1 mg) was added dropwise. After the mixture was stirred for 2 h, 5 mL of CH_2Cl_2 solution of bola **6, 10, 14, 18, 27, 40, 41 or 42** (2 mg) were given. The resulting suspension was stirred in the dark overnight. The membrane coated nanoparticles were isolated by repeated centrifugation, dispersion, and ultrasonification using CH_2Cl_2 as solvent and were used for further measurements.

In the first step of self-assembly, *meso*-(tetra-*m*-benzoyl chloride) porphyrin **32a**, was applied first it did not work at all. This activated porphyrin presumably formed domains on the silicate surface rather than spots of monomeric porphyrins, because it readily formed anhydride dimers upon partial hydrolysis of the acid chlorides, which

could not be totally avoided when applied. The more stable mixed anhydrides **32b** made with ethyl chloroformate were much more reliable and give wide exact 2 nm gap. The fluorescence of the bottom porphyrin **32b** was measured and a porphyrins, which diameter is larger than the well, for example, [T2PyP] porphyrin **35** (32 Å), should not reach the bottom at all. It proved, however, to be difficult to demonstrate this filter effect with the silicate particles. It did not work at all when the porphyrin tetracarbamoylchloride **32a** was used in the first self-assembly step porphyrin **35** (32 Å) having diameter larger than pores also enter into the gap. This activated porphyrin **32a** presumably formed domains on the silicate surface rather than spots of monomeric porphyrins, because it readily formed anhydride dimers upon partial hydrolysis of the acid chlorides. The more stable mixed anhydrides **32b** made with ethyl chloroformate were much more reliable and give a light population of monomeric porphyrin 2 nm gaps.

% of Yoctowells on aminated Silica particles

The procedure to load the aminated silica particles with porphyrin **32** activated with ethyl chloroformate to produce particle yoctowells was as follows: 30 mg of aminated silica particles (= 2.1×10^{13} particles with a total surface of 6.5×10^{17} nm^2) were suspended in 0.5 mL of a 10^{-4} M solution of the anhydride **32** in dichloromethane (= 3×10^{20} porphyrin molecules) and left standing for 2 h. If one considers the minimal area of a tetraphenylporphyrin with 4 nm^2, then 1.6×10^{17} molecules could be bound to the amino surface of these 30 mg of silica particles. The solution provided a 200-fold excess. The bola acid chloride (**27**, **41** or **42**) in CH_2Cl_2 was then added (0.5 mL; 10^{-3} M) and the mixture was stirred overnight. The particles were centrifuged (4000 rpm) and washed three times with CH_2Cl_2, ultrasonicated for 1 min and again centrifuged. The last supernatant was non-fluorescent.

Time Dependent fluorescence quenching experiments:

3 mg of the silicate colloids coated with nanowells were dispersed in 3 ml of water, ethanol and chloroform in a quartz cuvette. 200 µl of an aqueous solution of the quencher such as Mn(III)-*meso*-tetra(3-methyl-pyridinium)-porphyrinate chloride **33**, **34**, or **36** in water (10^{-4}M) or ethanol (10^{-4}M), or of Mn(III)-*meso*-(tetraphenyl) porphyrinate chloride **37** in $CHCl_3$ (10^{-4}M), were added to a solution stirred with a pipette. The fluorescence intensity of the bottom porphyrin at 650 nm was then measured over periods between 1 and 24 h.

Fluorescence measurements and time-dependent quenching experiments were performed on a Perkin-Elmer spectrometer (LS50B).

Manganese(III)-porphyrinate **33, 34** and **36** were then added in water or in ethanol solution, manganese(III)tetraphenyl porphyrinate **37** in chloroform solution, and the decrease of the bottom porphyrin´s fluorescence peak at 650 nm was measured with time. After a short time lag of about 5 seconds, which was caused by the slow response of the spectrometer, a non-exponential, in some cases sigmoid decrease was observed for all three yoctowells and all three solvents.

3 mg of the silicate colloids coated with yoctowells were dispersed in 3 ml of water, ethanol and chloroform in a quartz cuvette. 200 µl of an aqueous solution of the quencher such as Mn(III)-*meso*-tetra(3-methyl-pyridinium)-porphyrinate chloride **33**, **34**, or **36** in water (10^{-4}M) or ethanol (10^{-4}M), or of Mn(III)-*meso*-(tetraphenyl)porphyrinate chloride **37** in $CHCl_3$ (10^{-4}M), were added to a solution stirred with a pipette. The fluorescence intensity of the bottom porphyrin at 650 nm was then measured over periods between 1 and 24 h.

Sorting of three molecules within the yoctowells

3.0 mg of the particles with a surface of 6.5 x 10^{16} nm^2 or a maximum of 1.6 x 10^{16} adsorbed porphyrin molecules in a flat-lying orientation were then re-dissolved in 3.0 mL of chloroform or water. They showed absorption bands with an optical density corresponding always approx. to 3-4 x 10^{-7} M solutions or 5-6x10^{14} porphyrin molecules or yoctowells. These numbers were evaluated individually with an error of

± 5% for each experiment. The percentage of porphyrin-covered silica was thus about 3-4 %; 96-97 % of the particle surface was then covered by the bola walls.

About 3 mg of these particles were weighed in and 200 μL of a 10^{-4} M porphyrin or chlorin solution was added (= $1.2x10^{16}$ porphyrin molecules). This number is about twenty times higher than that of the yoctowells, about 5% of the molecules were trapped by the yoctowells. The rest may be largely adsorbed to the extended OEG-surface of the particles and was washed off in the three cleaning cycles after each loading. The twenty-fold excess was found to be a minimum for total quenching. A larger excess was avoided, because we did not want to fill-up the yoctowells with one type of porphyrin molecule only. The loading with the chlorin **39** was undertaken in chloroform/ethanol = 10:1 in order to dissolve the chlorin and suspend the particles efficiently.

3.1 mg of the particles were first suspended and then 200 μL of the 10^{-4} M of chlorin **39** solution was added. The solution was left standing for 1 h and then filled with some pressure from the syringe into a short steel HPLC column with a 200 nm cellobiose ultrafilter and a 100 nm steel frit (Duracell). The filtrate appeared as a clear solution. The cellobiose filter was then dropped into water or chloroform depending on its further progressing. Solution and filter were shortly and mildly sonicated, the solution decanted and filled up to 3.0 mL. UV/vis and fluorescence spectra were measured and 200 μL of the next porphyrin **33** solution (10^{-4} M) was added. Another filtration or a centrifugation procedure followed. Each filtration and re-dispersion procedure was accompanied by a loss of 10-20% of the particles, each centrifugation and re-dispersion by a loss of about 5-10%.

Electrochemical characterization of yoctowells

Cyclic voltammetry (CV).

This was performed using a potentiostat PG310 (HEKA) operated with an IBM compatible PC in an one-compartment three-electrode cell. The working electrode was a circular bar gold electrode or monolayer-coated gold electrode with a surface of

0.5 cm^2. The counter electrode was a Pt wire. An aqueous SCE was chosen as reference electrode. An aqueous solution containing 0.1 M KCl and 1 mM $K_3[Fe(CN)_6]$ was used as electrolyte. Before each experiment this solution was purged with argon for 10 min at room temperature and kept under argon atmosphere during measurements.

Procedure: 100 mg of dry silica particles was dispersed in 1 ml of ethyl acetate. After a short sonification (10 s) a small amount of silver paste solution was added. The resulting mixture was spun on ITO or gold electrodes by spin coating and dried in air (24 h) for electrochemical measurements. Cyclic voltammogram (CV) was performed in 0.1 M CH_2Cl_2 solution of $TBAPF_6$ using a potentiostate PG310 (HEKA) operated with an IBM compatible PC in an one-compartment three-electrode cell. Particle-modified ITO or gold electrodes (0.5 cm^2) were used as working electrode. The counter electrode was a Pt wire and Ag/AgCl was chosen as reference electrode. For electrochemical characterization of monomer a platinum disk electrode (0.16 cm^2) was employed as working electrode. Particles with redox-inactive porphyrins on top, naked silica particle as well as the particle without any cover molecule were used for control experiments. An irreversible reduction wave for Mn(III)→Mn(II) was found only, when the Mn(III) porphyrin **33** was on top of the yoctowells.

Fluorescence Quenching Experiments. Fluorescence measurements and quenching experiments were performed on a Perkin-Elmer spectrometer (LS50B).

~3 mg of the particles with $(OEG)_2$- yoctowells was first suspended in milli-Q water and then 100 μL of the 0.1 M solution of spermin **44** or 100 μL of the 10^{-4} M of tobramycin **45** or 100 μL of the polylysine **46** (Mo. Wt. 120.000, 0.1 mg in 5 mL) was added. Then the quencher 1,4-naphtho quinone-2-sulphonic acid sodium salt (100 μL of the 10^{-4} M solution) added and blocking effect of these molecules was measured by fluorescence spectrometer.

Same experiment was performed with yoctowell made up of alkane bolaamphiphile **42** and blocking effect of tobramycin **46** was observed by quenching with 1,4-naphthoquinone-2-sulphonic acid sodium salt.

For sulfamic acid: ~3 mg of the particles with $(OEG)_2$- yoctowells were first suspended in milli-Q water and sulfamic acid **47** (100 μL of the 0.1 M) was added. Then the yoctowell with sulfamic acid **47** was treated with 1,4-benzoquinone-2,5-trimethylammonium salt (100 μL of 10^{-4} M), 1,4-benzoquinone-2,5-disulphonic acid sodium salt (100 μL of 10^{-4} M) and tetrhydroxy-1,4-benzoquinone (100 μL of 10^{-4} M) and fluorescence was measured.

Blocking effect of cellobiose and *trans*-1,2-cyclohexane diol in yoctowell on silica particles. The particles with a coating made of *meta*-tetranhydride porphyrin **32** and alkane-bola **42** (10 Å), **6** (OEG_2-bola) and **10** (triglycinyl-bola) were kept overnight in a 0.1 M solutions of cellobiose as well as in second experiment with *trans*-1,2-cyclohexane diol, centrifuged (for yoctowells made of bola alkane **42** and triglycine **10**), redispersed, and centrifuged twice in distilled water, and their fluorescence was measured. It was within a possible error of ±20%, the same as that before addition of cellobiose or trans-1,2-cyclohexane diol. Addition of a large excess of Cu(II)TPPS **33a** did not diminish the fluorescence at all in the case of yoctowell made from alkane-bolaamphiphile **42**; the pore was irreversibly clogged under these conditions. Where as for the functional yoctowells prepared from bolaamphiphile **6** and **10** found no blocking effect at all, quencher Cu(II)TPPS **33a** enter inside the gap and quenches fluorescence of bottom porphyrin quantitatively.

Binding of fluoresceintriglycine tag to walls of triglycinyl yoctowells:

In Water: 3 mg of the particles (triglycinyl yoctowells) were first suspended in milli-Q water and then 200 μL of the 10^{-3} M of fluoresceintriglycine tag **43** solution was added. The solution was left standing for overnight and then filled with some pressure from the syringe into a short steel HPLC column with a 200 nm cellobiose ultrafilter and a 100 nm steel frit (Duracell). The residue was washed 4 times with milli-Q water final filtrate appeared as a clear solution. The cellobiose filter was then dropped into water. The solution and filter were shortly and mildly sonicated, the solution decanted and filled up to 3.0 mL. UV/vis and fluorescence spectra were measured.

In ethanol: 3 mg of the particles with triglycinyl yoctowells were first suspended in ethanol and then 200 μL of the 10^{-3} M of fluoresceintriglycine tag **43** solution was

added. The solution was left standing for overnight. The nanoparticles with fluoresceintriglycine tag **43** were isolated by repeated centrifugation, dispersion, and ultrasonification. Finally the fluorescence of redispersed particles was measured in ethanol.

Preparation of Schiff base within the yoctowells

100 mg of silicate particles with yoctowells were dispersed in 10 mL ethanol. To the dispersed solution 100 mg of 4,4'-diaminostilbene dihydrochloride was added and ultrasonificate for 10 min. The resulting mixture was refluxed at 90 ^{o}C for 4 hrs. The mixture was cooled at room temperature. The particles were collected by centrifugation (4000 rpm), washed with water (two times) and ethanol (three times). The last supernatant was non-fluorescent.

Fluorescence Quenching Experiments. Fluorescence measurements and quenching experiments were performed on a Perkin-Elmer spectrometer (LS50B).

~3 mg of the particles with ketone- yoctowells with stilbene bridge was first suspended in 3ml ethanol , then the quencher Mn **(**III)TPPS **32** was addeded and the fluorescence quenching of trans-4,4`-diaministilbene bridge and of the bottom porphyrin was measured by fluorescence spectrometer.

7.4 Abbreviations used

A	Ampere
AFM	Atomic Force Microscopy
BOC	*tert*-Butyloxycyrbonyl
Bola	Bolaamphiphile
b. p.	Boiling point
CV	Cyclic Voltammetry
DCM	Dichloromethane
d	Doublet
dd	doublets doublet
D_2O	Deuterium Oxide
EI	Electron Impact
Et	Ethyl
FAB	Fast Atom Bombardement
Fs	Fluorescence spectrum
g	gram
GABA	γ-amino butyric acid
Hz	Hertz
hrs.	hours
IR	Infrared
M.P.	Melting point
m	Multiplet
MHz	Megahertz
Ms	Mass spectrum
NMR	Nuclear Magnetic Resonance
ppm	parts per million
q	Quartet
RT	Room Temperature
s	Singlet
TEM	Transmission electron microscopy
t	Triplet
T	Temperature in K
UV	Ultraviolet
vis	visible