SUPPLEMENTARY INFORMATION

Synthesis of Diaminopimelic Acid (DAP)-containing *Mycobacterium* Peptidoglycan (PGN) Fragments and Their Modulation of Innate Immune Responses

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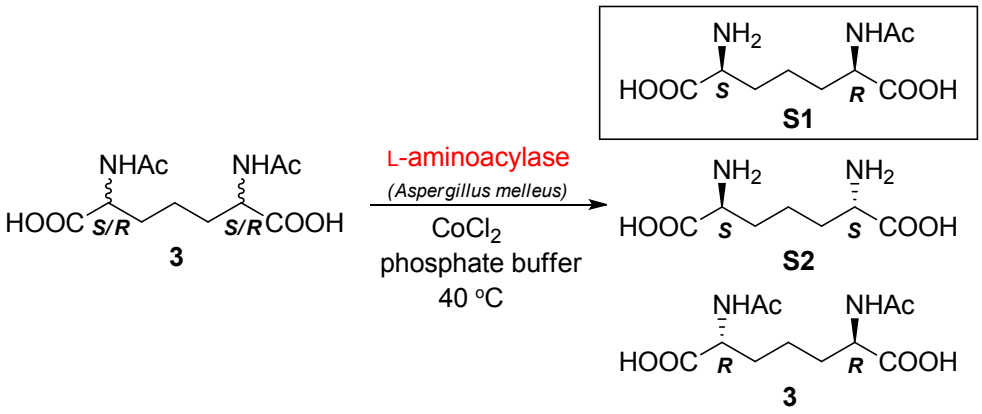
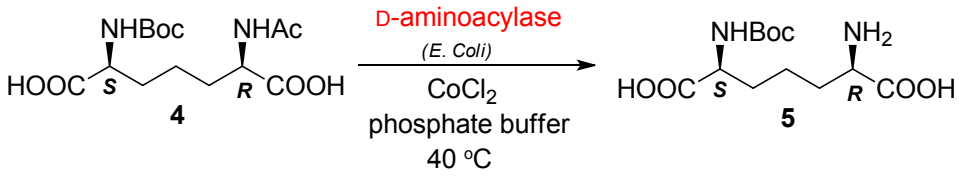
Enzymatic reactions of acetyl DAP



entry	**3**	$CoCl_2 \cdot 6H_2O$	phosphate buffer (pH 8.0)	time	yield [1)]
1	0.05 M	none	0.05 M	4 d	32%
2	0.05 M	1.0 mM	0.05 M	4 d	60%
3	0.05 M	10 mM	0.05 M	4 d	50-60%

[1)] The yield was determined by ^{1}H NMR.

Table S1. Preparation of (*2S*,*6R*)-6-acetyl -DAP (**S1**) with L-aminoacylase



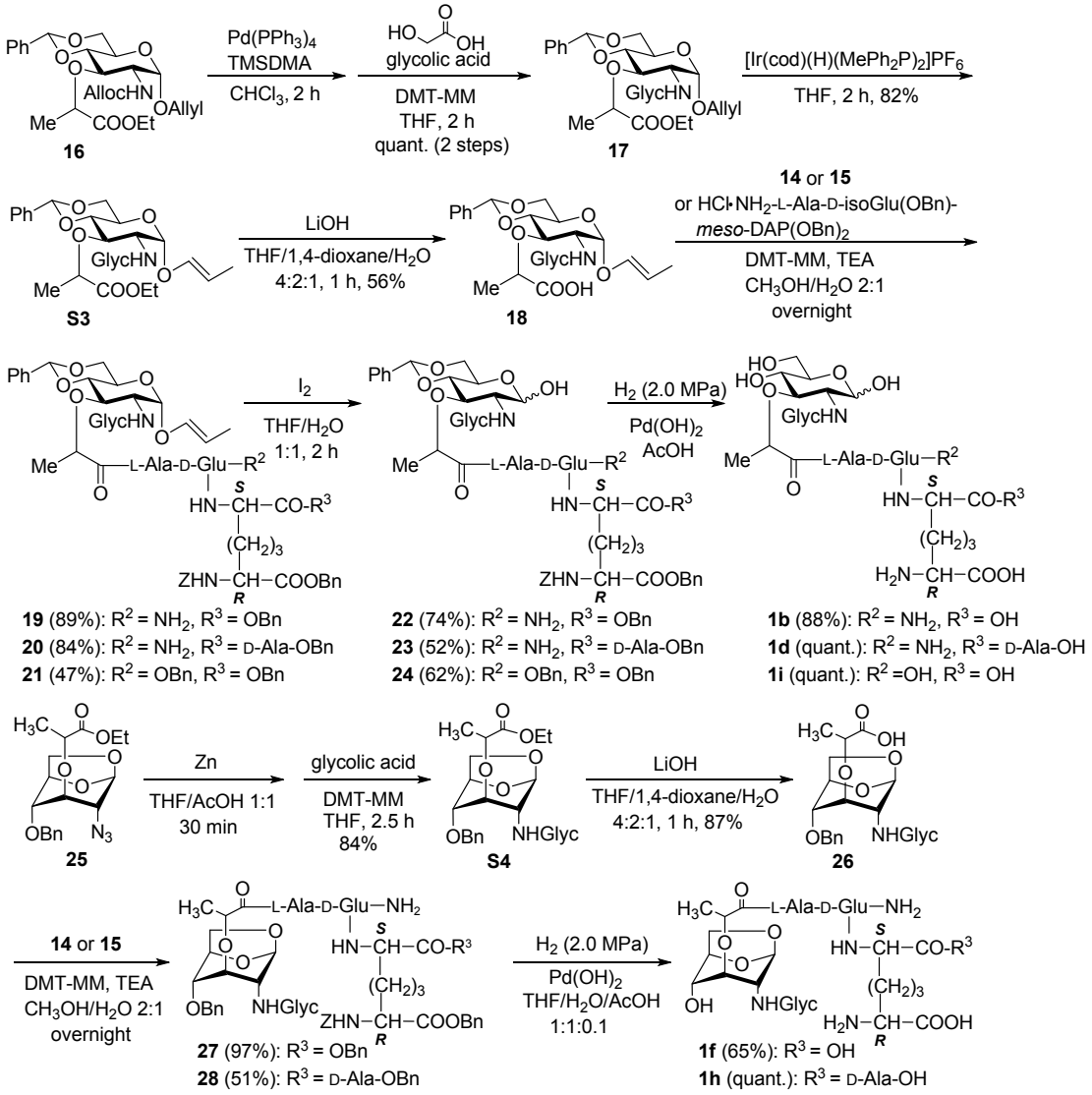
entry	**4**	$CoCl_2 \cdot 6H_2O$	phosphate buffer (pH 8.0)	time	yield [1)]
1	0.05 M	none	0.05 M	4 d	10%
2	0.05 M	1.0 mM	0.05 M	4 d	32%
3	0.05 M	10 mM	0.05 M	4 d	67%
4	0.05 M	10 mM	0.05 M	8 d	83%

[1)] The yield was determined by ^{1}H NMR.

Table S2. Preparation of (*2S*,*6R*)-2-*tert*-butyloxycarbonyl-DAP (**5**) with D-aminoacylase

Synthetic Procedures and spectroscopic data

For **Schemes 2** and **S1**:



Scheme S1. Preparation of *N*-glycolyl monosaccharide containing PGN fragments.

1-Allyl-2-glycolylamino-4,6-*O*-benzylidene-2-deoxy-3-*O*-[(*R*)-1-(ethoxycarbonyl)-ethyl]-α-D-glucopyranoside (17): To the solution of compound **16** (400 mg, 0.814 mmol) in $CHCl_3$ (20 mL) was added $Pd(PPh_3)_4$ (188 mg, 0.163 mmol) and (dimethylamino)trimethylsilane (528 uL, 3.26 mmol) under Argon atmosphere. The resulting solution was stirred at room temperature for 2 h. The reaction was quenched with H_2O, and extracted with $CHCl_3$ three times. The combined organic layers were washed with saturated aq. $NaHCO_3$, brine and dried over Na_2SO_4, and then concentrated in vacuo. Without any purification, the residue was reacted with glycolic acid (93 mg, 1.22 mmol), DMT-MM (450.5 mg, 1.63 mmol) in THF (10 mL) at room temperature. After 2 h, the reaction was quenched with H_2O, and extracted with

$CHCl_3$ three times. The combined organic layers were washed with saturated aq. $NaHCO_3$, brine and dried over Na_2SO_4, and then concentrated in vacuo. The crude compound was purified by silica-gel flash column chromatography (AcOEt/toluene 1:1.5) to give compound **17** as a yellow solid (378.9 mg, quant.).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.57–7.35 (6H, m; N<u>H</u>, Ar<u>H</u>), 5.91-5.83 (1H, m; -O-CH_2-C<u>H</u>=CH_2), 5.58 (1H, s; Ph-C<u>H</u>=O_2), 5.26 (1H, ddd, *J* = 1.6 Hz, 3.2 Hz, 17.3 Hz; -O-CH_2-CH=C<u>H</u>H), 5.20-5.17 (2H, m; -O-CH_2-CH=CH<u>H</u>, H-1), 4.48 (1H, q, *J* =7.1 Hz; Lac-α<u>H</u>), 4.27 (1H, dd, *J* = 4.6 Hz, 10.0 Hz; H-6'), 4.23-4.07 (6H, m; -COOC<u>H</u>$_2$$CH_3$, -NHCOC<u>H</u>$_2$OH, -O-C<u>H</u>H-CH=$CH_2$, H-2), 4.00 (1H, ddt, *J* = 1.3 Hz, 6.0 Hz, 12.9 Hz; -O-CH<u>H</u>-CH=CH_2), 3.88-3.69 (4H, m; H-5, H-3, H-6, H-4), 3.33 (1H, t, *J* = 6.3 Hz; -NHCOCH$_2$O<u>H</u>), 1.39 (3H, d, *J* = 7.0 Hz; Lac-βCH_3), 1.26 (3H, t, *J* =7.15 Hz; -COOCH$_2$C<u>H</u>$_3$). ^{13}C NMR ($CDCl_3$, 125 MHz): δ 174.9, 172.5, 137.2, 133.6, 132.9, 132.1, 132.1, 132.0, 129.0, 125.8, 101.3, 97.0, 83.3, 75.4, 75.3, 68.9, 68.8, 62.9, 62.2, 61.3, 53.3, 18.8, 14.0. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{23}H_{31}NO_9Na$: 488.1891 $[M+Na]^+$; found: 488.1892.

1-propenyl-2-glycolylamino-4,6-*O*-benzylidene-2-deoxy-3-*O*-[(*R*)-1-(ethoxycarbnyl)ethyl]-α-D-glucopyranoside (S3): $[Ir(cod)(MePh_2P)_2]PF_6$ (21.8 mg, 0.0256 mmol) was activated by H_2 in dry THF (2 mL) and added to the dry THF solution (3 mL) of compound **17** (300 mg, 0.644 mmol). The mixture was allowed to stir at room temperature for 2 h, then H_2O was added and extracted with ethyl acetate twice. The combined organic layers were washed with saturated aq. $NaHCO_3$, brine and dried over Na_2SO_4, and then concentrated in vacuo. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/acetone 20:1) to give compound **S3** as a pale yellow solid (246 mg, 82%).

^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.65 (1H, d, *J* = 1.2 Hz; N<u>H</u>), 7.46-7.37 (5H, m; Ar<u>H</u>), 6.10 (1H, dq, *J* = 1.6 Hz, 12.2 Hz; -O-C<u>H</u>=CH-), 5.58 (1H, s; Ph-C<u>H</u>=O_2), 5.37 (1H, d, *J* = 3.4 Hz; H-1), 5.16-5.09 (1H, m; -O-CH=C<u>H</u>-), 4.49 (1H, q, *J* = 7.0 Hz; Lac-α<u>H</u>), 4.28-4.06 (6H, m; H-2, H-6, -COOC<u>H</u>$_2$$CH_3$, -NHCOC<u>H</u>$_2$OH), 3.86-3.70 (4H, m; H-3, H-5, H-4, H-6'), 3.09 (1H, dd, *J* = 5.2 Hz, 6.9 Hz; NHCOCH$_2$O<u>H</u>), 1.54 (3H, dd, *J* = 1.6 Hz, 6.9 Hz; -CH=CH-C<u>H</u>$_3$), 1.41 (3H, d, J = 7.0 Hz; Lac-βCH_3), 1.27 (3H, t, *J* = 7.2 Hz; -COOCH$_2$C<u>H</u>$_3$). ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 175.0, 172.7, 142.8, 137.2, 129.0, 128.3, 125.8, 105.3, 101.4, 96.9, 83.1, 75.3, 75.1, 68.8, 63.1, 62.1, 61.4, 53.2, 18.8, 14.1, 12.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{23}H_{31}NO_9Na$: 488.1891 $[M+Na]^+$; found: 488.1896.

1-Propenyl-2-glycolylamino-4,6-*O*-benzylidene-2-deoxy-3-*O*-[(*R*)-1-(carbonyloxy)ethyl]-α-D-glucopyranoside (18): Compound S3 (255 mg, 0.548 mmol) and $LiOH·H_2O$ (25.3 mg) were dissolved in THF/1,4-dioxane/H_2O 4:2:1 (7

mL) and stirred at room temperature for 1 h. Then the solution was neutralized with Dowex H^+ and filtrated. After evaporation, the residue was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH/AcOH 15:1:0.1) to give compound **18** as a white solid (134 mg, 56%).

^{1}H NMR (400 MHz, CD_3OD): δ 7.47-7.33 (5H, m; ArH), 6.16 (1H, dd, *J* = 1.6 Hz, 12.4 Hz; -O-CH=CH-), 5.63 (1H, s; Ph-CH=O_2), 5.39 (1H, d, *J* = 3.2 Hz; H-1), 5.17-5.09 (1H, m; -O-CH=CH-), 4.44 (1H, q, *J* = 6.8 Hz; Lac-αH), 4.16-3.90 (5H, m; H-2, H-6, H-5, -NHCOCH_2OH), 3.81-3.74 (3H, m; H-3, H-4, H-6'), 1.53 (3H, dd, *J* = 1.6 Hz, 6.9 Hz; -CH=CH-CH_3), 1.34 (3H, d, *J* = 6.9 Hz; Lac-βCH_3); ^{13}C NMR (100 MHz, CD_3OD): δ 178.9, 175.8, 144.5, 139.0, 129.9, 129.2, 127.2, 105.7, 102.8, 98.1, 84.3, 77.6, 75.4, 69.7, 68.1, 64.7, 62.7, 55.1, 19.4, 12.4; HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{21}H_{27}NO_9Na$: 460.1578 $[M+Na]^+$; found: 460.1580.

Protected monosaccharide containing *N*-glycolylmuramyl group and tripeptide (19): To the solution of compound **18** (46 mg, 0.107 mmol) and **14** (50 mg, 0.071 mmol) in MeOH/H_2O 2:1 (18 mL) was added triethylamine (30 μL, 0.213 mmol). The mixture was stirred at room temperature for 10 min before DMT-MM was added. The resulting solution was allowed to react overnight. After dissolving the white solid with water, the mixture was extracted with $CHCl_3$. The organic layer was washed with 10% citric acid solution, saturated aq. $NaHCO_3$, brine and dried over Na_2SO_4, and then concentrated in vacuo. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give compound **19** as a white solid (71 mg, 89%).

^{1}H NMR (500 MHz, $CDCl_3$:CD_3OD 10:1): δ 7.46-7.30 (20 H, m; ArH), 6.11 (1H, d, *J* = 12.3 Hz; -O-CH=CH-), 5.57 (1H, s; Ph-CH=O_2), 5.19-5.05 (8H, m; -O-CH=CH-, H-1, -CH_2Ph × 3), 4.49-4.43 (2H, m; Gln-αH, DAP 2-H), 4.33-4.18 (5H, m; H-2, H-6, Lac-αH, Ala-αH, DAP 6-H), 4.02 (2H, d, *J* = 5.3 Hz; -NHCOCH_2OH), 3.86-3.67 (4H, m; H-3, H-4, H-5, H-6'), 2.32-2.24 (2H, m; Gln-γCH_2), 2.11 (1H, br s; Gln-βCH), 1.91 (1H, br s; Gln-βCH), 1.83-1.60 (4H, m; DAP 3-CH_2, 5-CH_2), 1.54 (3H, d, *J* = 6.9 Hz; -CH=CH-CH_3), 1.39-1.34 (8H, m; Lac-βCH_3, Ala-βCH_3, DAP 4-CH_2). ^{13}C NMR (125 MHz, $CDCl_3$:CD_3OD 10:1): δ 174.5, 174.4, 174.0, 173.7, 173.1, 172.4, 156.5, 142.4, 137.1, 136.3, 135.3, 129.2, 128.7, 128.6, 128.6, 128.4, 128.3, 128.3, 128.1, 127.9, 126.0, 106.1, 101.7, 97.5, 81.6, 78.0, 68.8, 67.3, 67.3, 67.1, 63.3, 62.0, 53.9, 53.8, 52.6, 52.5, 52.3, 52.1, 32.1, 31.8, 31.0, 28.7, 21.6, 19.4, 17.3, 12.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{58}H_{70}N_6O_{17}Na$: 1145.4690 $[M+Na]^+$; found: 1145.4686.

Protected monosaccharide containing *N*-glycolylmuramyl group and tetrapeptide (20): Compound **20** was synthesized from **18** and **15** with similar method to the synthesis of **19**. The crude compound was purified by silica-gel flash

column chromatography ($CHCl_3$/MeOH 20:1) to give compound **20** as a white solid (31 mg, 84%). ^{1}H NMR (400 MHz, $CDCl_3$:CD_3OD 10:1): δ 7.47-7.29 (20 H, m; ArH), 6.12 (1H, dd, *J* = 1.6 Hz, 12.4 Hz, ; -O-CH=CH-), 5.57 (1H, s; Ph-CH=O_2), 5.22-5.04 (8H, m; -O-CH=CH-, H-1, -CH_2Ph × 3), 4.53 (1H, q, *J* = 7.1 Hz; D-Ala-αH), 4.40-4.15 (7H, m; Gln-αH, DAP 2-H, H-2, H-6, Lac-αH, Ala-αH, DAP 6-H), 4.00 (2H, s; -NHCOCH_2OH), 3.86-3.68 (4H, m; H-3, H-4, H-5, H-6'), 2.29-2.18 (3H, m; Gln-γCH_2, βCH), 1.83-1.64 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.55 (3H, dd, *J* = 1.2 Hz, 6.8 Hz; -CH=CH-CH_3), 1.40-1.32 (11H, m; Lac-βCH_3, Ala-βCH_3, D-Ala-βCH_3, DAP 4-CH_2). ^{13}C NMR (100 MHz, $CDCl_3$:CD_3OD 10:1): δ 174.4, 173.9, 173.7, 173.2, 172.8, 172.6, 172.1, 156.2, 142.4, 137.1, 135.5, 135.4, 129.2, 128.7, 128.6, 128.6, 128.5, 128.4, 128.3, 128.0, 127.8, 126.1, 106.2, 101.7, 97.5, 81.2, 78.1, 77.8, 68.8, 67.3, 67.1, 63.4, 62.0, 54.0, 53.6, 52.4, 48.4, 31.8, 31.5, 31.0, 29.3, 21.7, 19.3, 17.2, 17.1, 12.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{61}H_{75}N_7O_{18}Na$: 1216.5061 $[M+Na]^+$; found: 1216.5076.

Protected monosaccharide containing *N*-glycolylmuramyl group and tripeptide (21): Compound **21** was synthesized from **18** and HCl·NH_2-L-Ala-D-isoGlu-*meso*-DAP with similar method to the synthesis of **19**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 50:1) to give compound **21** as a white solid (25 mg, 47%).^{1}H NMR (400 MHz, $CDCl_3$): δ 7.47-7.45 (2H, m; NH × 3), 7.35-7.11 (25H, m; ArH), 6.71 (1H, d, *J* = 8.0 Hz; NH), 6.10 (1H, d, *J* = 11.7 Hz; -O-CH=CH-), 5.57 (1H, s; Ph-CH=O_2), 5.46 (1H, d, *J* = 8.2 Hz; OH), 5.19-5.01 (10H, m; -O-CH=CH-, H-1, -CH_2Ph × 4), 4.51-4.38 (2H, m; Gln-αH, DAP 2-H), 4.29-4.25 (5H, m; H-2, H-6, Lac-αH, Ala-αH, DAP 6-H), 4.11-3.96 (2H, m; -NHCOCH_2OH), 3.88-3.67 (4H, m; H-3, H-4, H-5, H-6'), 2.27-2.06 (4H, m; Gln-γCH_2, Gln-βCH_2), 1.77-1.59 (4H, m; DAP 3-CH_2, 5-CH_2), 1.53 (3H, d, *J* = 6.7 Hz; -CH=CH-CH_3), 1.42-1.26 (8H, m; Lac-βCH_3, Ala-βCH_3, DAP 4-CH_2). ^{13}C NMR (100 MHz, $CDCl_3$): δ 174.1, 173.9, 172.5, 172.3, 172.1, 171.1, 156.2, 142.3, 137.1, 135.2, 135.2, 129.1, 128.7, 128.3, 128.2, 128.1, 126.0, 106.1, 101.6, 97.5, 82.1, 68.8, 67.4, 67.3, 63.2, 62.4, 53.9, 53.8, 52.1, 52.0, 51.9, 49.7, 32.0, 31.6, 31.0, 26.9, 21.2, 19.6, 17.8, 12.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{65}H_{75}N_5O_{18}Na$: 1236.4999 $[M+Na]^+$; found: 1236.5015.

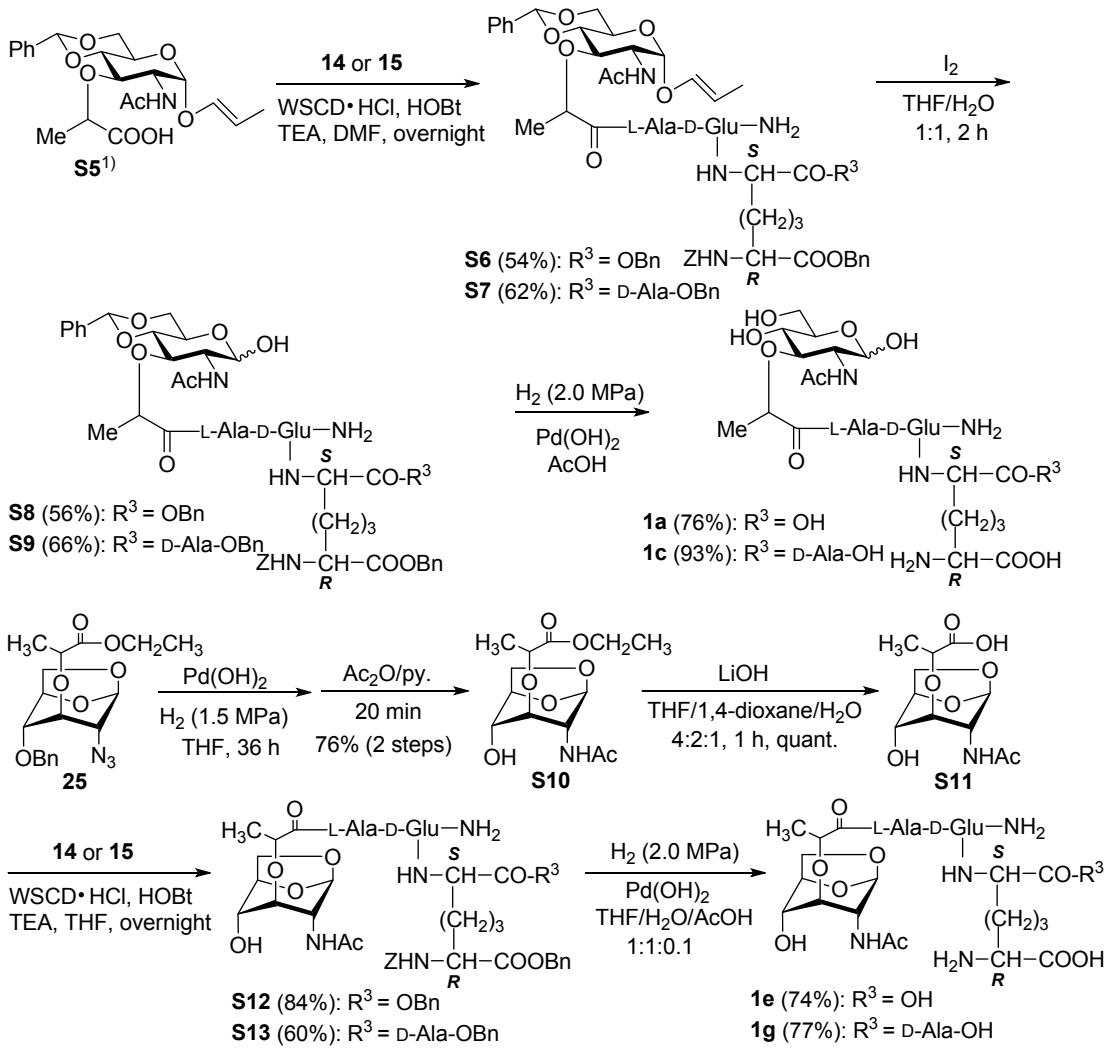
1-*O*-Deprotected monosaccharide containing *N*-glycolylmuramyl group and tripeptide (22): To the solution of compound **19** (50 mg, 0.045 mmol) in THF/H_2O 2:1 (7.5 mL) was added I_2 (23 mg, 0.089 mmol). The reaction mixture was stirred at room temperature for 2 h. The reaction was quenched by addition of 10% aqueous $Na_2S_2O_3$ and the mixture was extracted with $CHCl_3$ three times. The combined organic layers were washed with 10% aq. $Na_2S_2O_3$, saturated aq. $NaHCO_3$, and brine, dried over Na_2SO_4, and concentrated in vacuo. The crude compound was purified by

silica-gel flash column chromatography ($CHCl_3$/MeOH 15:1) to give compound **22** as a white solid (23 mg, 74%). ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.22 (1H, d, *J* = 6.8 Hz; NH), 8.14 (1H, d, *J* = 8.2 Hz; NH), 7.72 (1H, d, *J* = 7.8 Hz; NH), 7.66 (1H, d, *J* = 8.5 Hz; NH), 7.42-7.33 (22 H, m; ArH, NH × 2), 7.03-7.00 (2H, m; NH, 1-OH), 5.69 (1H, s; Ph-CH=O_2), 5.47 (1H, t, *J* = 5.3 Hz; -NHCOCH_2OH), 5.10-5.00 (7H, m; H-1, -CH_2Ph ×3), 4.29-3.57 (13H, m; Gln-αH, DAP 2-H, H-2, H-6, Lac-αH, Ala-αH, DAP 6-H, -NHCOCH_2OH, H-3, H-4, H-5, H-6'), 2.15-2.11 (2H, m; Gln-γCH_2), 1.91 (1H, br s; Gln-βCH), 1.67-1.58 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.34 (2H, br s; DAP 4-CH_2), 1.22-1.18 (6H, m; Lac-βCH_3, Ala-βCH_3).
^{13}C NMR (125 MHz, DMSO-d_6): δ 173.0, 172.1, 172.1, 172.0, 171.9, 171.9, 171.8, 156.1, 137.6, 136.8, 135.9, 135.9, 128.7, 128.3, 128.3, 128.0, 128.0, 127.9, 127.8, 127.7, 127.6, 125.9, 125.8, 100.3, 91.4, 81.2, 76.6, 75.9, 68.1, 65.9, 65.8, 65.5, 62.1, 61.3, 53.8, 53.0, 52.1, 51.9, 48.0, 31.5, 30.2, 30.2, 27.7, 21.9, 18.9, 18.2. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{55}H_{66}N_6O_{17}Na$: 1105.4377 $[M+Na]^+$; found: 1105.4381.

1-*O*-Deprotected monosaccharide containing *N*-glycolylmuramyl group and tetrapeptide (23): Compound **23** was synthesized from **20** with similar method to the synthesis of **22**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 15:1) to give compound **23** as a white solid (14 mg, 52%). ^{1}H NMR (500 MHz, DMSO-d_6): δ 8.33 (1H, d, *J* = 7.3 Hz; NH), 8.13 (1H, d, *J* = 8.2 Hz; NH), 7.87 (1H, d, *J* = 8.0 Hz; NH), 7.70 (1H, d, *J* = 7.6 Hz; NH), 7.66 (1H, d, *J* = 8.9 Hz; NH), 7.44-7.26 (21 H, m; ArH, NH × 2), 7.02 (1H, d, *J* = 3.5 Hz; 1-OH), 6.99 (1H, s; NH), 5.68 (1H, s; Ph-CH=O_2), 5.46 (1H, t, *J* = 5.8 Hz; -NHCOCH_2OH), 5.12-4.98 (7H, m; H-1, -CH_2Ph ×3), 4.31-3.66 (14H, m; D-Ala-αH, Gln-αH, DAP 2-H, H-2, H-6, Lac-αH, Ala-αH, DAP 6-H, -NHCOCH_2OH, H-3, H-4, H-5, H-6'), 2.15-2.08 (2H, m; Gln-γCH_2), 1.98-1.92 (1H, m; Gln-βCH), 1.69-1.27 (7H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2, 4-CH_2), 1.26-1.18 (9H, m; Lac-βCH_3, Ala-βCH_3, D-Ala-βCH_3). HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{58}H_{71}N_7O_{18}Na$: 1176.4748 $[M+Na]^+$; found: 1176.4761.

1-*O*-Deprotected monosaccharide containing N-glycolylmuramyl group and tripeptide (24): Compound **24** was synthesized from **21** with similar method to the synthesis of 22. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 25:1) to give compound **24** as a white solid (12 mg, 62%). ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.43 (1H, d, *J* = 7.6 Hz; NH), 7.70 (1H, d, *J* = 7.8 Hz; NH), 7.64 (1H, d, *J* = 9.2 Hz; NH), 7.40-7.24 (26 H, m; ArH, NH), 5.66 (1H, s; Ph-CH=O_2), 5.07-4.97 (9H, m; H-1, -CH_2Ph ×3), 4.35-4.12 (5H, m; Gln-αH, DAP 2-H, Lac-αH, Ala-αH, H-4), 4.03-3.98 (4H, m; -NHCOCH_2OH, DAP 6-H, H-2), 3.90-3.64 (4H, m; H-6, H-3, H-4, H-5, H-6'), 2.18-2.14 (2H, m; Gln-γCH_2), 1.96 (1H,

br s; Gln-βC<u>H</u>), 1.81-1.53 (5H, m; Gln-βC<u>H</u>, DAP 3-C<u>H</u>$_2$, 5-C<u>H</u>$_2$), 1.32 (2H, br s; DAP 4-C<u>H</u>$_2$), 1.22-1.18 (6H, m; Lac-βC<u>H</u>$_3$, Ala-βC<u>H</u>$_3$). ^{13}C NMR (100 MHz, DMSO-d_6): δ 172.6, 172.4, 172.3, 172.0, 171.9, 171.7, 171.6, 170.7, 156.4, 137.8, 137.0, 136.0, 135.7, 128.9, 128.6, 128.3, 128.2, 128.0, 127.8, 126.1, 126.0, 100.5, 91.6, 81.3, 76.9, 76.1, 68.3, 66.5, 66.2, 66.0, 66.7, 62.4, 56.8, 54.0, 53.2, 52.2, 52.0, 31.3, 30.8, 30.4, 28.8, 26.9, 22.0, 19.0, 19.0. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{62}H_{71}N_5O_{18}Na$: 1196.4686 $[M+Na]^+$; found: 1196.4702.



Scheme S2. Preparation of *N*-acetyl monosaccharide containing PGN fragments.

1) A. Kawasaki, Y. Karasudani, Y. Otsuka, M. Hasegawa, N. Inohara, Y. Fujimoto, K. Fukase, *Chemistry* **2008**, *14*, 10318-10330.

Protected monosaccharide containing *N*-acetylmuramyl group and tripeptide (S6): To the solution of compound **S5** (45 mg, 0.107 mmol), **14** (50 mg, 0.071 mmol), WSCD·HCl (20.5 mg, 0.107 mmol), and HOBt (14.4 mg, 0.107 mmol) in dry DMF was added triethylamine (30 μL, 0.214 mmol) at 0 °C under Argon atmosphere. The

mixture was allowed to stir overnight at room temperature. 10% citric acid solution was added to the mixture and extracted with ethyl acetate three times. The combined organic layers were washed with saturated aq. $NaHCO_3$ and brine, dried over Na_2SO_4, and concentrated in vacuo. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give compound **S6** as a white solid (40 mg, 54%). ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.22 (1H, d, J = 7.1 Hz; NH), 8.18 (1H, d, J = 8.0 Hz; NH), 8.13 (1H, d, J = 8.0 Hz; NH), 7.72 (1H, d, J = 7.6 Hz; NH), 7.56 (1H, d, J = 7.3 Hz; NH), 7.44-7.29 (21 H, m; ArH, NH), 7.00 (1H, s; NH), 6.22 (1H, dd, J = 1.6 Hz, 12.4 Hz ; -O-CH=CH-), 5.70 (1H, s; Ph-CH=O_2), 5.12-4.98 (8H, m; -O-CH=CH-, H-1, -CH_2Ph × 3), 4.33-4.00 (7H, m; Ala-αH, Gln-αH, DAP 2-H, 6-H, Lac-αH, H-2, H-5), 3.79-3.62 (4H, m; H-4, H-3, H-6, H-6'), 2.14-2.10 (2H, m; Gln-γCH_2), 1.96-1.89 (1H, m; Gln-βCH), 1.81 (3H, s; -NHCOCH_3), 1.75-1.56 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.51 (3H, dd, J = 1.4 Hz, 6.9 Hz; -CH=CH-CH_3), 1.35 (2H, br s; DAP 4-CH_2), 1.22-1.19 (6H, m; Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (125 MHz, $CDCl_3$:CD_3OD 10:1): δ 174.9, 174.2, 173.8, 173.3, 172.4, 171.8, 156.6, 142.7, 141.8, 137.2, 136.3, 135.4, 129.2, 128.7, 128.6, 128.6, 128.4, 128.3, 128.1, 126.1, 105.8, 101.7, 97.4, 81.7, 78.3, 68.9, 67.3, 67.1, 63.4, 53.9, 53.4, 52.6, 52.2, 32.2, 31.7, 31.0, 28.7, 22.8, 21.7, 19.5, 17.2, 12.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{58}H_{70}N_6O_{16}Na$: 1129.4741 $[M+Na]^+$; found: 1129.4751.

Protected monosaccharide containing *N*-acetylmuramyl group and tetrapeptide (S7): Compound **S7** was synthesized from **S5** and **15** with similar method to the synthesis of **S6**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give compound **S7** as a white solid (21 mg, 62%). ^{1}H NMR (500 MHz, $CDCl_3$:CD_3OD 8:1): δ 7.46-7.30 (20 H, m; ArH), 6.11 (1H, d, J = 12.1 Hz ; -O-CH=CH-), 5.56 (1H, s; Ph-CH=O_2), 5.15-5.08 (8H, m; -O-CH=CH-, H-1, -CH_2Ph × 3), 4.53-4.12 (8H, m; D-Ala-αH, Ala-αH, Gln-αH, DAP 2-H, 6-H, Lac-αH, H-2, H-5), 3.82-3.68 (4H, m; H-4, H-3, H-6, H-6'), 2.24 (3H, br s; Gln-γCH_2, Gln-βCH), 1.94 (3H, s; NHCOCH_3), 1.86-1.62 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.56 (3H, d, J = 6.0 Hz; -CH=CH-CH_3), 1.40-1.35 (11H, m; Lac-βCH_3, Ala-βCH_3, D-Ala-βCH_3, DAP 4-CH_2). ^{13}C NMR (125 MHz, $CDCl_3$:CD_3OD 8:1): δ 173.8,173.7, 173.1, 172.6, 172.5, 172.1, 171.4, 156.4, 142.5, 137.2, 136.3, 135.5, 135.4, 129.1, 128.7, 128.6, 128.6, 128.5, 128.3, 128.3, 128.2, 128.1, 128.0, 127.8, 126.0, 105.8, 101.6, 97.5, 81.1, 78.3, 68.8, 67.2, 671, 67.0, 67.0, 63.4, 54.0, 53.8, 53.0, 50.1, 31.8, 31.6, 31.0, 29.9, 23.0, 21.7, 19.4, 17.3, 17.0, 12.3.

HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{61}H_{75}N_7O_{17}Na$: 1200.5112 $[M+Na]^+$; found: 1200.5122.

1-*O*-Deprotected monosaccharide containing *N*-acetylmuramyl group and tripeptide (S8): Compound **S8** was synthesized from **S6** with similar method to the

synthesis of **22**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 15:1) to give compound **S8** as a white solid (20 mg, 56%). ^{1}H NMR (500 MHz, DMSO-d_6): δ 8.22 (1H, d, J = 7.5 Hz; NH), 8.13 (1H, d, J = 8.5 Hz; NH), 8.04 (1H, d, J = 7.8 Hz; NH), 7.72 (1H, d, J = 7.3 Hz; NH), 7.55 (1H, d, J = 7.0 Hz; NH), 7.44-7.26 (21 H, m; ArH, NH), 7.00 (1H, s; NH), 6.90 (1H, d, J = 4.6 Hz; 1-OH), 5.68 (1H, s; Ph-CH=O_2), 5.10-4.99 (7H, m; H-1, -CH_2Ph × 3), 4.30-3.65 (11H, m; Ala-αH, Gln-αH, DAP 2-H, 6-H, Lac-αH, H-2, H-3, H-4, H-5, H-6, H-6'), 2.14-2.11 (2H, m; Gln-γCH_2), 1.91 (1H, br s; Gln-βCH), 1.81 (3H, s; NHCOCH_3), 1.72-1.56 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.34 (2H, br s; DAP 4-CH_2), 1.24-1.19 (6H, m; Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (125 MHz, DMSO-d_6): δ 173.0, 172.1, 172.1, 171.9, 171.8, 169.5, 156.1, 137.7, 136.8, 135.9, 128.7, 128.3, 128.0, 128.0, 127.9, 127.8, 127.7, 127.6, 125.9, 125.8, 100.3, 91.4, 81.2, 76.7, 75.8, 68.1, 65.9, 65.7, 65.5, 62.1, 53.8, 53.7, 52.1, 51.9, 48.1, 31.5, 30.2, 30.1, 27.8, 22.6, 21.9, 18.9, 18.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{55}H_{66}N_6O_{16}Na$: 1089.4428 $[M+Na]^+$; found: 1089.4435.

1-*O*-Deprotected monosaccharide containing *N*-acetylmuramyl group and tetrapeptide (S9): Compound **S9** was synthesized from **S7** with similar method to the synthesis of **22**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 12:1) to give compound **S9** as a white solid (10.2 mg, 66%). ^{1}H NMR (500 MHz, DMSO-d_6): δ 8.32 (1H, d, J = 7.1 Hz; NH), 8.13 (1H, d, J = 8.0 Hz; NH), 8.05 (1H, d, J = 8.0 Hz; NH), 7.87 (1H, d, J = 8.0 Hz; NH), 7.70 (1H, d, J = 7.3 Hz; NH), 7.54 (1H, d, J = 7.0 Hz; NH), 7.44-7.26 (21 H, m; ArH, NH), 6.99 (1H, s; NH), 6.91 (1H, d, J = 4.2 Hz; -OH), 5.68 (1H, s; Ph-CH=O_2), 5.11-4.98 (7H, m; H-1, -CH_2Ph × 3), 4.29-3.60 (12H, m; D-Ala-αH, Ala-αH, Gln-αH, DAP 2-H, 6-H, Lac-αH, H-2, H-3, H-4, H-5, H-6, H-6'), 2.14-2.10 (2H, m; Gln-γCH_2), 1.93 (1H, br s; Gln-βCH), 1.81 (3H, s; NHCOCH_3), 1.71-1.33 (7H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2, DAP 4-CH_2), 1.26-1.19 (9H, m; D-Ala-βCH_3, Lac-βCH_3, Ala-βCH_3).
^{13}C NMR (125 MHz, DMSO-d_6): δ 173.1, 172.2, 172.2, 172.1, 172.0, 171.5, 171.3, 169.5, 156.1, 137.7, 136.8, 135.9, 135.9, 128.7, 128.4, 128.3, 128.3, 128.0, 127.9, 127.9, 127.8, 127.6, 127.6, 125.9, 125.8, 123.7, 123.1, 100.3, 91.4, 81.2, 76.7, 75.9, 68.1, 65.8, 65.8, 65.5, 62.1, 54.0, 53.7, 52.1, 51.9, 48.1, 47.6, 31.8, 31.7, 30.2, 27.9, 22.7, 21.8, 18.9, 18.2, 16.9. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{58}H_{71}N_7O_{17}Na$: 1160.4799 $[M+Na]^+$; found: 1160.4807.

Monosaccharide containing *N*-acetylmuramyl group and tripeptide (1a) and monosaccharide containing *N*-acetylmuramyl group and tetrapeptide (1c) Compounds **1a** and **1c** were synthesized from **S8** and **S9** respectively, with similar method to the synthesis of **1b**.

Compound **1a** (yield 76% from **S8**): ^{1}H NMR (500 MHz, D_2O): δ 5.08 (1H, d, J = 3.6

Hz; H-1β), 4.25-4.13 (4H, m; Ala-αH, Gln-αH, Lac-αH, DAP 2-H), 3.89-3.60 (5H, m; H-2, H-3, H-5, H-6, DAP 6-H), 3.51-3.38 (2H, m; H-4, H-6'), 2.33-2.30 (2H, m; Gln-γCH_2), 2.13-2.05 (1H, m; Gln-βCH), 1.96-1.89 (4H, m; Gln-βCH, NHCOCH_3), 1.86-1.61 (4H, m; DAP 3-CH_2, 5-CH_2), 1.42-1.28 (8H, DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (125 MHz, D_2O): δ 176.5, 176.5, 175.7, 175.2, 175.1, 174.8, 174.5, 91.5, 80.2, 76.2, 72.0, 69.5, 61.0, 55.0, 54.7, 54.2, 53.5, 50.3, 32.2, 31.3, 30.6, 27.4, 22.5, 21.7, 19.2, 17.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{26}H_{44}N_6O_{14}Na$: 687.2808 $[M+Na]^+$; found: 687.2812.

Compound **1c** (yield 93% from **S9**):^{1}H NMR (500 MHz, D_2O): δ 5.08 (1H, d, J = 3.5 Hz; H-1β), 4.24-4.18 (5H, m; D-Ala-αH, Ala-αH, Gln-αH, Lac-αH, DAP 2-H), 3.90-3.60 (5H, m; H-2, H-3, H-5, H-6, DAP 6-H), 3.51-3.38 (2H, m; H-4, H-6'), 2.34-2.31 (2H, m; Gln-γCH_2), 2.14-2.05 (1H, m; Gln-βCH), 1.93-1.62 (8H, m; Gln-βCH, NHCOCH_3, DAP 3-CH_2, 5-CH_2), 1.41-1.28 (11H, DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3, D-Ala-βCH_3). ^{13}C NMR (125 MHz, D_2O): δ 180.4, 176.6, 176.5, 175.7, 175.5, 175.2, 174.7, 173.5, 91.6, 80.2, 76.4, 72.2, 69.7, 61.2, 55.2, 54.5, 54.3, 53.5, 51.6, 50.4, 32.2, 31.5, 30.7, 27.6, 22.7, 21.7, 19.3, 18.2, 17.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{29}H_{49}N_7O_{15}Na$: 758.3179 $[M+Na]^+$; found: 758.3191.

2-Acetylamino-1,6-anhydro-2-deoxy-3-*O*-[(1*R*)-1-(ethyoxycarbonyl)ethyl]-β-D-glucopyranose (S10): $Pd(OH)_2$ was added to the THF solution (2 mL) of compound **25** (100 mg, 0.265 mmol) and the mixture was stirred for 36 h under H_2 (1.5 MPa) atmosphere. After that time, $Pd(OH)_2$ was removed by membrane filtration, and the filtrate was concentrated in vacuo. Acetic anhydride (1 mL) and pyridine (1 mL) were added to the above residue and reacted for 20 min. The solution was concentrated in vacuo and the residue was purified directly by silica-gel flash column chromatography (toluene/AcOEt 15:1) to give compound **S10** as a white solid (61 mg, 76%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.42 (1H, d, J = 8.3 Hz; NH), 5.37 (1H, s; H-1), 4.50 (1H, d, J = 5.5 Hz; H-5), 4.29 (1H, d, J = 6.9 Hz; Lac-αH), 4.25–4.17 (3H, m;, -COOC$H_2$$CH_3$, H-6), 4.08 (1H, d, J = 8.7 Hz; H-2), 3.77-3.70 (2H, m; H-4, H-6'), 3.42 (1H, s; H-3), 2.00 (3H, s; -NHCOCH_3), 1.42 (3H, d, J = 6.9 Hz; Lac-βCH_3), 1.29 (3H, t, J = 7.1 Hz; -$COOCH_2CH_3$). ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.9, 169.8, 101.1, 77.9, 74.1, 70.5, 65.3, 61.2, 50.3, 23.2, 18.1, 14.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{13}H_{21}NO_7Na$: 326.1210 $[M+Na]^+$; found: 326.1212.

2-Acetylamino-1,6-anhydro-2-deoxy-3-*O*-[(1*R*)-1-(carbonyl)ethyl]-β-D-glucopyranose (S11): Compound **S11** was synthesized from **S10** with similar method to the synthesis of **26**. Compound **S11** was used without further purification.

Protected monosaccharide containing *N*-acetylmuramyl(anh) group and tripeptide (S12): Compound **S12** was synthesized from **S11** and **14** with similar method to the synthesis of **S6**. The crude compound was purified by silica-gel flash

column chromatography ($CHCl_3$/MeOH 15:1) to give compound **S12** as a white solid (52.4 mg, 84%). ^{1}H NMR (500 MHz, $CDCl_3$:CD_3OD 20:1): δ 7.93 (1H, d, J = 6.2 Hz; NH), 7.73 (1H, d, J = 7.5 Hz; NH), 7.69 (1H, d, J = 7.5 Hz; NH), 7.36-7.25 (20H, m; ArH, NH), 6.97 (1H, d, J = 9.0 Hz; NH), 5.99 (1H, d, J = 8.5 Hz; NH), 5.9 (1H, s; NH), 5.39 (1H, s; H-1), 5.17-5.06 (6H, m; -CH_2Ph × 3), 4.54-4.43 (3H, m; DAP 2-H, H-5, Gln-αH), 4.33-4.28 (2H, m; DAP 6-H, Ala-αH), 4.25 (1H, d, J = 7.5 Hz; H-6), 4.11 (1H, d, J = 6.0 Hz; Lac-αH), 3.96 (1H, s; H-2), 3.75 (1H, dd, J = 6.0 Hz, 7.5 Hz; H-6'), 3.67 (1H, s; H-4), 3.38 (1H, s; H-3), 2.34-2.23 (2H, m; Gln-γCH_2), 2.11 (1H, br s; Gln-βCH), 1.98 (3H, s; -NHCOCH_3), 1.95-1.91(1H, m; Gln-βCH), 1.84-1.64 (4H, m; DAP 3-CH_2, 5-CH_2), 1.41-1.34 (8H, m; DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3).
^{13}C NMR (125 MHz, $CDCl_3$:CD_3OD 20:1): δ 174.2, 173.9, 173.7, 173.4, 172.5, 172.4, 170.8, 136.3, 135.4, 128.7, 128.6, 128.6, 128.4, 128.3, 128.3, 128.1, 100.7, 78.9, 76.3, 75.4, 69.2, 67.3, 67.3, 67.1, 65.2, 53.9, 52.6, 52.0, 48.1, 32.2, 31.7, 30.9, 29.0, 22.8, 22.8, 21.6, 17.7, 17.0. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{48}H_{60}N_6O_{15}Na$: 983.4009 $[M+Na]^+$; found: 983.4005.

Protected monosaccharide containing *N*-acetylmuramyl(anh) group and tetrapeptide (S13): Compound **S13** was synthesized from **S11** and **15** with similar method to the synthesis of **S6**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give compound **S13** as a white solid (19 mg, 60%). ^{1}H NMR (500 MHz, $CDCl_3$:CD_3OD 20:1): δ 7.95 (1H, d, J = 6.5 Hz; NH), 7.68 (1H, br s; NH), 7.36-7.25 (20H, m; ArH), 6.90 (1H, d, J = 9.0 Hz; NH), 5.99 (1H, d, J = 8.3 Hz; NH), 5.70 (1H, s; NH), 5.39 (1H, s; H-1), 5.16-5.01 (6H, m; -CH_2Ph × 3), 4.56-4.52 (2H, m; D-Ala-αH, Gln-αH), 4.38 (1H, dd, J = 2.9 Hz, 10.8 Hz; H-5), 4.34-4.31 (2H, m; DAP 2-H, 6-H), 4.28-4.22 (2H, m; Ala-αH, H-6), 4.11 (1H, q, J = 6.6 Hz; Lac-αH), 3.98 (1H, s; H-2), 3.75 (1H, dd, J = 6.2 Hz, 6.2 Hz; H-6'), 3.67 (1H, s; H-4), 3.40 (1H, s; H-3), 2.29-2.20 (3H, m; Gln-γCH_2, βCH), 1.97 (3H, s; -NHCOCH_3), 1.90-1.58 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.44-1.35 (11H, m; DAP 4-CH_2, D-Ala-βCH_3, Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (125 MHz, $CDCl_3$:CD_3OD 20:1): δ 174.0, 173.7, 173.0, 172.6, 172.5, 172.2, 170.8, 170.7, 135.6, 135.4, 128.7, 128.6, 128.6, 128.5, 128.4, 128.3, 128.2, 128.1, 100.7, 78.9, 76.2, 75.4, 68.9, 67.2, 67.0, 65.2, 54.0, 53.5, 51.0, 48.4, 31,8, 31.5, 31.1, 29.8, 22.8, 21.7, 17.9, 17.0, 17.0. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{51}H_{65}N_7O_{16}Na$: 1054.4380 $[M+Na]^+$; found: 1054.4386.

Monosaccharide containing *N*-acetylmuramyl(anh) group and tripeptide (1e) and (1g)

Compounds **1e** and **1g** were synthesized from **S12** and **S13** respectively, with similar method to the synthesis of **1f**.

Compound **1e** (yield 74% from **S12**): ^{1}H NMR (500 MHz, D_2O): δ 5.41 (1H, s; H-1),

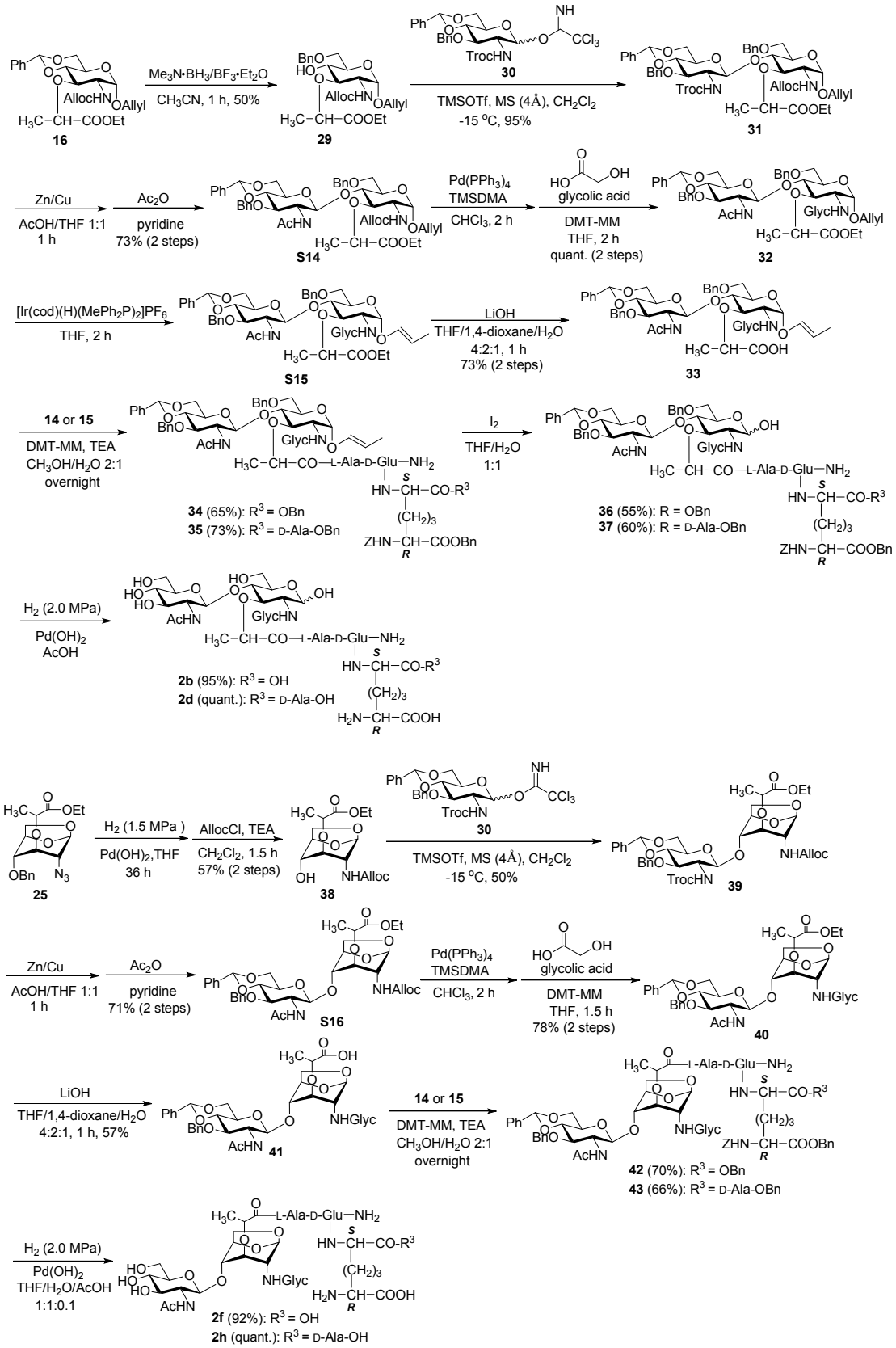
4.61 (1H, d, *J* = 5.6 Hz; H-5), 4.29-4.18 (4H, m; Ala-αH, Gln-αH, H-6, DAP 2-H), 4.10 (1H, q, *J* = 6.9 Hz; Lac-αH), 3.85 (1H, s; H-2), 3.83-3.79 (2H, m; DAP 6-H, H-4), 3.73 (1H, dd, *J* = 5.9 Hz, 7.7 Hz; H-6'), 3.33 (1H, s; H-3), 2.35-2.32 (2H, m; Gln-γCH_2), 2.14-2.06 (1H, m; Gln-βCH), 1.94 (3H, s; -NHCOCH_3), 1.91-1.67 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.45-1.40 (2H, m; DAP 4-CH_2), 1.36 (3H, d, *J* = 7.2 Hz; Ala-βCH_3), 1.29 (3H, d, *J* = 6.9 Hz;, Lac-βCH_3). ^{13}C NMR (125 MHz, D_2O): *δ* 177.1, 177.0, 176.8, 176.2, 176.1, 174.8, 174.7, 101.1, 79.6, 77.0, 77.0, 69.2, 66.3, 55.1, 54.0, 50.8, 50.6, 32.6, 31.3, 30.8, 27.9, 22.9, 22.1, 19.1, 17.8.

HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{26}H_{43}N_6O_{13}$: 647.2883 $[M+H]^+$; found: 647.2905.

Compound **1g** (yield 77% from **S13**): ^{1}H NMR (500 MHz, D_2O): *δ* 5.41 (1H, s; H-1), 4.61 (1H, d, *J* = 5.7 Hz; H-5), 4.33-4.18 (5H, m; Ala-αH, D-Ala-αH, Gln-αH, H-6, DAP 2-H), 4.10 (1H, q, *J* = 6.9 Hz; Lac-αH), 3.90-3.85 (2H, m; DAP 6-H, H-2), 3.79 (1H, d, *J* = 1.3 Hz; H-4), 3.73 (1H, dd, *J* = 5.8 Hz, 7.8 Hz; H-6'), 3.33 (1H, dd, *J* = 1.6 Hz, 1.6 Hz; H-3), 2.34-2.30 (2H, m; Gln-γCH_2), 2.14-2.06 (1H, m; Gln-βCH), 1.93 (3H, s; -NHCOCH_3), 1.90-1.65 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.45-1.40 (2H, m; DAP 4-CH_2), 1.36 (3H, d, *J* = 7.3 Hz; Ala-βCH_3), 1.33 (3H, d, *J* = 7.3 Hz; D-Ala-βCH_3), 1.29 (3H, d, *J* = 6.9 Hz;, Lac-βCH_3). ^{13}C NMR (125 MHz, D_2O): *δ* 176.8, 176.4, 176.3, 175.6, 175.6, 174.3, 174.2, 173.4, 100.5, 79.0, 76.4, 68.5, 65.7, 54.1, 53.8, 53.3, 50.3, 50.0, 49.3, 32.0, 31.1, 30.1, 27.4, 22.3, 21.3, 18.6, 17.1, 16.6.

HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{29}H_{48}N_7O_{14}$: 718.3254 $[M+H]^+$; found: 718.3269.

For **Schemes 3** and **S3**:



Scheme S3. Preparation of *N*-glycolyl disaccharide containing PGN fragments.

1-Allyl-2-allyloxycarbonylamino-6-benzyloxy-2-deoxy-4-hydroxyl-3-*O*-[(*R*)-1-(ethoxycarbonyl)ethyl]-α-D-glucopyranoside (29): To a solution of **16** (1.0 g, 2.03 mmol) and trimethylamine-borane (297 mg, 4.07 mmol) in dry CH_3CN (6 mL) at 0 °C was added boron trifluoride diethyl etherate (1.54 mL, 12.18 mmol) dropwise and the mixture was stirred at 0 °C for 30 min and then warmed to room temperature and stirred for 1 h. The reaction was quenched with saturated aq. $NaHCO_3$ and extracted with ethyl acetate three times. The organic layer was washed with aq. 10% citric acid, saturated aq. $NaHCO_3$, and brine, dried over Na_2SO_4, and concentrated in vacuo. The crude compound was purified by silica-gel flash chromatography (toluene/AcOEt 8:1) to give compound **29** as a white solid (502 mg, 50%).

^{1}H NMR (500 MHz, DMSO-d_6): δ 7.37-7.26 (5H, m; Ar<u>H</u>), 7.50 (1H, d, *J* = 5.9 Hz; N<u>H</u>), 5.88 (2H, m; -O-CH_2-C<u>H</u>=CH_2 × 2), 5.47 (1H, d, *J* = 7.2 Hz; 4-O<u>H</u>), 5.27 (2H, dd, *J* = 1.2 Hz, 17.2 Hz; -O-CH_2-CH=C<u>H</u>H × 2), 5.17 (1H, ddd, *J* = 1.3 Hz, 3.0 Hz, 10.5 Hz; -O-CH_2-CH=CH<u>H</u>), 5.12 (1H, dd, *J* = 1.5 Hz, 10.5 Hz; -O-CH_2-CH=CH<u>H</u>), 4.92 (1H, d, *J* = 3.3 Hz; H-1), 4.61 (1H, q, *J* = 6.9 Hz; Lac-α<u>H</u>), 4.51-4.46 (4H, m; PhC<u>H</u>$_2$-O-, -O-C<u>H</u>$_2$-CH=CH_2), 4.16-4.07 (3H, m; -O-C<u>H</u>H-CH=CH_2, -COOC<u>H</u>$_2$$CH_3$), 3.93 (1H, dd, *J* = 5.6 Hz, 13.6 Hz; -O-CH<u>H</u>-CH=CH_2), 3.67 (1H, m; H-6), 3.60-3.56 (2H, m; H-5, H-6'), 3.49 (1H, dd, *J* = 8.8 Hz, 10.8 Hz; H-3), 3.39-3.32 (2H, m; H-2, H-4), 1.31 (3H, d, *J* = 6.9 Hz; Lac-βC<u>H</u>$_3$), 1.20 (3H, t, *J* = 7.2 Hz; -COOCH_2C<u>H</u>$_3$);

^{13}C NMR (125 MHz, DMSO-d_6): δ 174.3, 155.6, 138.6, 134.4, 133.6, 128.2, 127.3, 127.3, 116.9, 116.6, 95.6, 77.7, 74.9, 72.3, 71.7, 70.8, 69.1, 67.3, 64.4, 60.7, 54.8, 18.7, 13.9; HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{25}H_{35}NO_9Na$: 516.2204 $[M+Na]^+$; found: 516.2205.

1-Allyl-2-allyloxycarbonylamino-6-*O*-benzyl-4-*O*-(3'-*O*-benzyl-4',6'-*O*-benzylidene-2'-deoxy-2'-(2,2,2-trichlorethoxycarbonylamino)-β-D-glucopyranosyl)-2-deoxy-3-*O*-[(*R*)-1-(ethoxycarbonyl)ethyl]-α-D-glucopyranoside (31): TMSOTf (6 μL, 0.0608 mmol) was added to a mixture of imidate **30** (309 mg, 0.456 mmol), glycosyl acceptor **29** (150 mg, 0.304 mmol), and MS4Å molecular sieves in dry CH_2Cl_2 (8 mL) at -15 °C. After the mixture had been stirred at the same temperature for 10 min, the reaction was quenched with chilled saturated aq. $NaHCO_3$, filtrated to remove the solid. The filtrate was extracted with CH_2Cl_2 twice, and the combined organic layers were washed with brine, dried over Na_2SO_4, and concentrated in vacuo. The crude compound was purified by silica-gel flash chromatography (toluene/AcOEt 10:1) to give **31** as a white solid (390 mg, 95%).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.53-7.12 (15H, m; Ar<u>H</u>), 7.08 (1H, s; N<u>H</u>), 6.00-5.80 (2H, m; -O-CH_2-C<u>H</u>=CH_2 × 2), 5.57 (1H, s, Ph-C<u>H</u>=O_2), 5.31-5.13 (5H, m; -O-CH_2-CH=C<u>H</u>$_2$ ×2, H-1), 4.88 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.87 (1H, d, *J* = 11.9 Hz; Ph-C<u>H</u>-O-), 4.65 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.84 (1H, d, *J* = 12.5 Hz; -O-C<u>H</u>-

CCl_3), 4.61-4.52 (4H, m; -O-C<u>H</u>-CCl_3, -O-C<u>H_2</u>-CH=CH_2, Lac-α<u>H</u>), 4.41 (1H, dd, *J* = 5.1 Hz, 10.5 Hz; H-6'), 4.29-4.11 (4H, m; Ph-C<u>H</u>-O-, -O-C<u>H_2</u>-CH_3, H-1'), 4.06 (1H, ddt, *J* = 1.3 Hz, 5.5 Hz, 13.1 Hz; -O-C<u>H</u>-CH=CH_2), 3.97 (1H, dd, *J* = 5.5 Hz, 13.1 Hz; -O-C<u>H</u>-CH=CH_2), 3.92 (1H, m; H-3), 3.77-3.56 (7H, m; H-6, H-6, H-6', H-4', H-4, H-2, <u>N</u>H), 3.49-3.41 (2H, m; H-2', H-5), 3.26-3.19 (2H, m; H-3', H-5'), 1.33 (3H, d, *J* = 7.1 Hz; Lac-βC<u>H_3</u>), 1.28 (3H, t, *J* = 7.2 Hz; -$COOCH_2C$<u>H_3</u>).

^{13}C NMR (125 MHz, $CDCl_3$): δ 175.4, 156.5, 154.0, 138.2, 137.7, 137.2, 134.0, 129.1, 129.1, 128.7, 128.4, 128.4, 128.3, 128.2, 127.8, 126.0, 117.3, 116.9, 101.2, 100.9, 96.5, 82.3, 77.9, 77.8, 75.2, 74.7, 74.6, 74.2, 73.8, 69.9, 69.0, 68.8, 67.1, 67.0, 65.6, 65.2, 61.3, 57.5, 55.2, 18.9, 14.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{48}H_{57}Cl_3N_2O_{15}Na$: 1031.2701 $[M+Na]^+$; found: 1031.2706.

1-Allyl-2-allyloxycarbonylamino-6-*O*-benzyl-4-*O*-(3'-*O*-benzyl-4',6'-*O*-benzylidene-2'-deoxy-2'-ethylamino-β-D-glucopyranosyl)-2-deoxy-3-*O*-[(*R*)-1-(ethoxycarbonyl)ethyl]-α-D-glucopyranoside (S14): Zn/Cu (prepared from 2 g of Zn) was added to a solution of **31** (380 mg, 0.377 mmol) in AcOH/THF 1:1 (10 mL), and the mixture was stirred at room temperature for 1 h. The insoluble materials were filtered off, and the filtrate was concentrated in vacuo. The residual solvent was removed by co-evaporation with toluene. The residue was dissolved in pyridine (5 mL) and acetic anhydride (5 mL), and the solution was stirred at room temperature overnight. The reagents were removed by concentration with toluene. The residue was purified by silica-gel flash chromatography (toluene/AcOEt 3:1) to give compound **S14** as a white solid (231 mg, 70%).

^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.53-7.14 (15H, m; Ar<u>H</u>), 7.06 (1H, s; N<u>H</u>), 5.97-5.81 (2H, m; -O-CH_2-C<u>H</u>=CH_2 × 2), 5.58 (1H, s, Ph-C<u>H</u>=O_2), 5.31-5.14 (5H, m; -O-CH_2-CH=C<u>H_2</u> × 2, H-1), 4.88 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.83 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.64 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.36 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.62-4.56 (3H, m; -O-C<u>H_2</u>-CH=CH_2, Lac-α<u>H</u>), 4.48-4.44 (2H, m; H-1', N<u>H</u>), 4.40 (1H, dd, *J* = 5.1 Hz, 10.3 Hz; H-6'), 4.27-4.08 (3H, m; -O-C<u>H_2</u>CH_3, -O-C<u>H</u>-CH=CH_2), 4.00-3.95 (2H, m; -O-C<u>H</u>-CH=CH_2, H-3), 3.76 (1H, dd, *J* = 10.5 Hz, 10.5 Hz; H-6'), 3.69-3.57 (7H, m; H-6, H-6, H-4', H-4, H-2, H-2', H-3'), 3.47 (1H, m; H-5), 3.29 (1H, m; H-5'), 1.74 (3H, s; -NHCOC<u>H_3</u>), 1.35 (3H, d, *J* = 7.1 Hz; Lac-βC<u>H_3</u>), 1.28 (3H, t, *J* = 7.3 Hz; -$COOCH_2C$<u>H_3</u>). ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 175.4, 169.8, 156.5, 138.5, 138.0, 137.3, 134.0, 133.5, 129.2, 129.1, 128.8, 128.5, 128.3, 128.1, 127.8, 126.0, 117.1, 116.9, 101.3, 100.3, 96.4, 82.7, 77.6,75.2, 74.8, 74.1, 73.6, 70.2, 68.9, 67.3, 65.7, 65.2, 61.3, 56.1, 55.2, 23.4, 18.8, 14.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{47}H_{58}N_2O_{14}Na$: 897.3780 $[M+Na]^+$; found: 897.3791.

1-Allyl-2-glycolylamino-6-*O*-benzyl-4-*O*-(3'-*O*-benzyl-4',6'-O-benzylidene-2'-de-

oxy-2'-ethylamino-β-D-glucopyranosyl)-2-deoxy-3-*O*-[(*R*)-1-(ethoxycarbonyl)ethyl]-α-D-glucopyranoside (32): Compound **32** was synthesized from **S14** with similar method to the synthesis of **17**. The crude compound was purified by silica-gel flash column chromatography (AcOEt/toluene 1:1) to give **32** as a pale yellow solid (116.3 mg, quant.).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.82 (1H, d, *J* = 6.1 Hz; NH), 7.53-7.14 (15H, m; ArH), 5.88-5.80 (1H, m; -O-CH_2-CH=CH_2), 5.58 (1H, s, Ph-CH=O_2), 5.25-5.15 (3H, m; -O-CH_2-CH=CH_2, H-1), 4.88 (1H, d, *J* = 12.1 Hz; Ph-CH-O-), 4.84 (1H, d, *J* = 12.1 Hz; Ph-CH-O-), 4.65 (1H, d, *J* = 12.1 Hz; Ph-CH-O-), 4.36 (1H, d, *J* = 12.1 Hz; Ph-CH-O-), 4.61(1H, q, *J* = 7.0 Hz; Lac-αH), 4.46-4.39 (3H, m; H-1', H-6', NH), 4.25-4.06 (5H, m; -O-CH_2CH_3, -$COCH_2$OH, -O-CH-CH=CH_2), 3.99-3.91 (3H, m; -O-CH-CH=CH_2, H-2, H-4), 3.75 (1H, dd, *J* = 10.3 Hz, 10.3 Hz; H-6'), 3.69-3.46 (7H, m; H-2', H-4', H-3', H-5, H-3, H-6, H-6), 3.31-3.26 (1H, m; H-5'), 3.02 (1H, dd, *J* = 6.2 Hz, 6.2 Hz; -$COCH_2$OH), 1.74 (3H, s; -NHCOCH_3), 1.33 (3H, d, *J* = 7.0 Hz; Lac-βCH_3), 1.27 (3H, t, *J* = 7.2 Hz; -$COOCH_2CH_3$). ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.0, 172.3, 169.8, 138.5, 137.9, 137.3, 133.8, 129.2, 129.1, 128.8, 128.5, 128.3, 128.1, 127.9, 126.0, 117.4, 101.3, 100.4, 96.2, 82.7, 77.7, 75.7, 74.8, 74.0, 73.7, 70.2, 68.9, 68.8, 67.2, 65.7, 62.0, 61.4, 56.0, 53.5, 23.4, 18.9, 14.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{45}H_{56}N_2O_{14}Na$: 871.3624 $[M+Na]^+$; found: 871.3627.

1-Propenyl-2-glycolylamino-6-*O*-benzyl-4-*O*-(3'-*O*-benzyl-4',6'-*O*-benzylidene-2'-deoxy-2'-ethylamino-β-D-glucopyranosyl)-2-deoxy-3-*O*-[(*R*)-1-(ethoxycarbonyl)ethyl]-α-D-glucopyranoside (S15): Compound **S15** was synthesized from **32** with similar method to the synthesis of **S3**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/acetone 15:1) to give compound **S15** as a pale white solid.

^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.95 (1H, d, *J* = 5.6 Hz; NH), 7.53-7.14 (15H, m; ArH), 6.09 (1H, d, *J* = 1.6 Hz, 12.3 Hz; -O-CH=CH-CH_3), 5.58 (1H, s, Ph-CH=O_2), 5.40 (1H, d, *J* = 3.3 Hz; H-1), 5.12-5.05 (1H, m; -O-CH=CH-CH_3), 4.88 (1H, d, *J* = 12.1 Hz; Ph-CH-O-), 4.83 (1H, d, *J* = 12.1 Hz; Ph-CH-O-), 4.65 (1H, d, *J* = 12.1 Hz; Ph-CH-O-), 4.34 (1H, d, *J* = 12.1 Hz; Ph-CH-O-), 4.62(1H, q, *J* = 7.0 Hz; Lac-αH), 4.45-4.38 (3H, m; H-1', H-6', NH), 4.26-4.05 (4H, m; -O-CH_2CH_3, -$COCH_2$OH), 3.99 (1H, dd, *J* = 9.6 Hz, 9.6 Hz; H-4), 3.94-3.90 (1H, m; H-2), 3.76 (1H, dd, *J* = 10.3 Hz, 10.3 Hz; H-6'), 3.70-3.44 (7H, m; H-2', H-4', H-3', H-5, H-3, H-6, H-6), 3.31-3.26 (1H, m; H-5'), 2.95 (1H, dd, *J* = 6.2 Hz, 6.2 Hz; -$COCH_2$OH), 1.73 (3H, s; -NHCH_3), 1.52 (3H, dd, *J* = 1.6 Hz, 6.9 Hz; -O-CH=CH-CH_3), 1.34 (3H, d, *J* = 7.0 Hz; Lac-βCH_3), 1.29 (3H, t, *J* = 7.2 Hz; -$COOCH_2CH_3$). ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 175.9, 172.4, 169.7, 143.1, 138.4, 137.8, 137.2, 129.2, 129.1, 128.7, 128.5, 128.4, 128.3, 128.0, 127.8, 126.0, 104.4, 101.2, 100.4, 96.2, 82.6, 77.6, 75.3, 74.8, 74.0, 73.6,

70.5, 68.8, 67.0, 65.7, 61.9, 61.4, 55.8, 53.4,23.4, 18.9, 14.1, 12.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{45}H_{56}N_2O_{14}Na$: 871.3624 $[M+Na]^+$; found: 871.3627.

1-Propenyl-2-glycolylamino-6-*O*-benzyl-4-*O*-(3'-*O*-benzyl-4',6'-*O*-benzylidene-2'-deoxy-2'-ethylamino-β-D-glucopyranosyl)-2-deoxy-3-*O*-[(*R*)-1-(carbonyl)ethyl]-α-D-glucopyranoside (33): Compound **33** was synthesized from **S15** with similar method to the synthesis of **18**. The yield of compound **33** was 73 % (calculated from **32**). HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{43}H_{52}N_2O_{14}Na$: 843.3311 $[M+Na]^+$; found: 843.3306.

Protected disaccharide containing *N*-glycolylmuramyl group and tripeptide (34): Compound **34** was synthesized from **33** and **14** with similar method to the synthesis of **19**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give **34** as a white solid (36 mg, 65 %).

^{1}H NMR (500 MHz, $CDCl_3$:CD_3OD 8:1): δ 7.44-7.20 (30 H, m; Ar<u>H</u>), 6.09 (1H, d, *J* = 12.4 Hz; -O-C<u>H</u>=CH-CH_3), 5.58 (1H, s; Ph-C<u>H</u>=O_2), 5.26 (1H, d, *J* = 2.9 Hz; H-1), 5.16-5.06 (7 H, m; -COOC<u>H</u>$_2$Ph × 3, -O-CH=C<u>H</u>-CH_3), 4.86 (1H, d, *J* = 11.9 Hz ; Ph-C<u>H</u>-O-), 4.76 (1H, d, *J* = 11.6 Hz ; Ph-C<u>H</u>-O-), 4.64 (1H, d, *J* = 11.9 Hz ; Ph-C<u>H</u>-O-), 4.56-4.53 (2H, m; Lac-α<u>H</u>, H-1'), 4.48-4.41 (3H, m; Ph-C<u>H</u>-O-, Gln-α<u>H</u>, DAP 2-<u>H</u>), 4.36-4.31 (2H, m; DAP 6-<u>H</u>, H-6'), 4.21-4.18 (1H, m; Ala-α<u>H</u>), 4.06-3.97 (4H, m; H-2, H-5, -COC<u>H</u>$_2$OH), 3.75 (1H, dd; *J* = 10.5 Hz, 10.5 Hz; H-6'), 3.66-3.41 (7H, m; H-6', H-4', H-2, H-3', H-3, H-6, H-6), 3.29-3.25 (1H, m; H-5'), 2.38-1.93 (4H, m; Gln-γC<u>H</u>$_2$, Gln-βC<u>H</u>$_2$), 1.85-1.63 (4H, m; DAP 3-C<u>H</u>$_2$, 5-C<u>H</u>$_2$), 1.81 (3H, s; -NHCOCH_3), 1.51 (3H, dd, *J* = 1.6 Hz, 6.9 Hz; -O-CH=CH-C<u>H</u>$_3$), 1.39-1.26 (8H, m; DAP 4-C<u>H</u>$_2$, Lac-βC<u>H</u>$_3$, Ala-βC<u>H</u>$_3$). HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{80}H_{95}N_7O_{22}Na$: 1528.6422 $[M+Na]^+$; found: 1528.6420.

Protected disaccharide containing N-glycolylmuramyl group and tetrapeptide (35): Compound **35** was synthesized from **33** and **15** with similar method to the synthesis of **19**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give **35** as a white solid (35 mg, 73 %).

^{1}H NMR (500 MHz, DMSO-d_6): δ 8.44 (1H, d, *J* = 5.7 Hz; N<u>H</u>), 8.34 (1H, d, *J* = 6.9 Hz; N<u>H</u>), 8.20 (2H, d, *J* = 7.7 Hz; N<u>H</u> ×2), 7.95 (1H, d, *J* = 7.5 Hz; N<u>H</u>), 7.88 (1H, d, *J* = 8.3 Hz; N<u>H</u>), 7.70 (1H, d, *J* = 7.6 Hz; N<u>H</u>), 7.44-7.20 (31H, m; Ar<u>H</u>, N<u>H</u>), 6.91 (1H, s; N<u>H</u>), 6.18 (1H, dd, *J* = 1.4 Hz, 12.2 Hz; -O-C<u>H</u>=CH-CH_3), 5.67 (1H, s; Ph-C<u>H</u>=O_2), 5.31 (1H, t, *J* = 5.9 Hz; -COCH_2O<u>H</u>), 5.20 (1H, d, *J* = 3.0 Hz; H-1), 5.12-4.98 (7 H, m; -COOC<u>H</u>$_2$Ph × 3, -O-CH=C<u>H</u>-CH_3), 4.78 (1H, d, *J* = 8.3 Hz; H-1'), 4.73 (1H, d, *J* = 11.9 Hz ; Ph-C<u>H</u>-O-), 4.50 (1H, d, *J* = 11.9 Hz ; Ph-C<u>H</u>-O-), 4.60-4.37 (4H, m; Ph-C<u>H</u>-O- ×2, Lac-α<u>H</u>, D-Ala-α<u>H</u>), 4.32-3.98 (6H, m; Ala-α<u>H</u>, H-6', DAP 2-<u>H</u>, 6-<u>H</u>, Gln-α<u>H</u>, H-3'), 3.89-3.50 (11H, m; H-4, H-6', H-4', H-2, H-2', H-6, H-6, H-3, H-5, -COC<u>H</u>$_2$OH), 3.24-3.22 (1H, m; H-5'), 2.18-2.13 (2H, m; Gln-γC<u>H</u>$_2$),

1.98-1.93 (1H, m; Gln-βCH), 1.82 (3H, s; -NHCOCH$_3$), 1.75-1.33 (5H, m; Gln-βCH, DAP 3-CH$_2$, 5-CH$_2$), 1.45 (3H, dd, *J* = 1.4 Hz, 6.7 Hz; -O-CH=CH-CH$_3$), 1.29-1.22 (11H, m; DAP 4-CH$_2$, Lac-βCH$_3$, Ala-βCH$_3$, D-Ala-βCH$_3$). ^{13}C NMR (125 MHz, DMSO-d$_6$): δ 173.4, 173.1, 172.7, 172.2, 171.9, 171.5, 171.3, 169.7, 156.1, 143.5, 138.7, 138.5, 137.6, 136.8, 135.9, 128.3, 128.3, 128.2, 128.0, 128.0, 128.0, 127.9, 127.8, 127.7, 127.6, 127.4, 127.3, 127.1, 126.0, 103.4, 100.2, 95.7, 81.3, 75.5, 74.5, 73.5, 71.7, 70.7, 68.0, 67.7, 65.9, 65.8, 65.5, 65.4, 61.3, 60.9, 54.0, 53.0, 52.2, 51.8, 48.0, 47.6, 31.8, 31.7, 30.2, 27.9,22.9, 21.8, 19.5, 18.8, 16.9, 12.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{83}H_{100}N_8O_{23}Na$: 1599.6794 $[M+Na]^+$; found: 1599.6788.

1-*O*-Deprotected disaccharide containing *N*-glycolylmuramyl group and tripeptide (36): Compound **36** was synthesized from **34** with similar method to the synthesis of **22**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give **36** as a white solid (17 mg, 55 %).

^{1}H NMR (500 MHz, DMSO-d$_6$): δ 8.27-8.23 (2H, m; NH × 2), 8.20 (1H, d, *J* = 7.9 Hz; NH), 8.16 (1H, d, *J* = 7.2 Hz; NH), 7.83 (1H, d, *J* = 6.6 Hz; NH), 7.76 (1H, d, *J* = 7.9 Hz; NH), 7.45-7.23 (31 H, m; ArH, NH), 6.97 (1H, s; NH), 6.72 (1H, d, *J* = 3.9 Hz; 1-OH), 5.69 (1H, s; Ph-CH=O$_2$), 5.33 (1H, t, *J* = 6.0 Hz; -COCH$_2$OH), 5.11-5.00 (7 H, m; -COOCH$_2$Ph × 3, H-1), 4.76-4.72 (2H, m; H-1', Ph-CH-O-), 4.62-4.52 (3H, m ; Ph-CH-O- × 3), 4.46 (1H, q, *J* = 6.3 Hz; Lac-αH), 4.41-4.00 (6H, m; Ala-αH, H-6', DAP 2-H, Gln-αH, DAP 6-H, H-3'), 3.81-3.47 (11H, m; H-4, H-6', H-4', H-2, H-2', H-6, H-6, H-3, H-5, -COCH$_2$OH), 3.25-3.20 (1H, m; H-5'), 2.17-2.14 (2H, m; Gln-γCH$_2$), 1.98-1.89 (1H, m; Gln-βCH), 1.84 (3H, s; -NHCOCH$_3$), 1.76-1.57 (5H, m; Gln-βCH, DAP 3-CH$_2$, 5-CH$_2$), 1.35 (2H, br s; DAP 4-CH$_2$), 1.25-1.22 (6H, m; Lac-βCH$_3$, Ala-βCH$_3$). ^{13}C NMR (125 MHz, DMSO-d$_6$): δ 173.4, 173.1, 172.3, 172.1, 172.0, 172.0, 171.8, 169.6, 156.2, 138.7, 138.6, 137.6, 136.8, 135.9, 135.9, 128.7, 128.4, 128.3, 128.2, 128.1, 128.1, 128.0, 128.0, 127.8, 127.7, 127.7, 127.4, 127.3, 127.1, 126.0, 100.1, 89.9, 81.3, 75.9, 75.8, 75.0, 73.5, 71.7, 69.8, 68.2, 68.0, 65.9, 65.8, 65.5, 65.4, 61.3, 53.8, 53.7, 52.2, 52.0, 48.1, 31.5, 30.2, 30.2, 27.8, 22.9, 21.9, 19.4, 18.6. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{77}H_{91}N_7O_{22}Na$: 1488.6109 $[M+Na]^+$; found: 1488.6106.

1-*O*-Deprotected disaccharide containing *N*-glycolylmuramyl group and tetrapeptide (37): Compound **37** was synthesized from **35** with similar method to the synthesis of **22**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 25:1) to give **37** as a white solid (19 mg, 60 %).

^{1}H NMR (400 MHz, DMSO-d$_6$): δ 8.34 (1H, d, *J* = 7.7 Hz; NH), 8.20-8.16 (2H, m; NH ×2), 8.10 (1H, d, *J* = 7.4 Hz; NH), 7.88 (1H, d, *J* = 8.0 Hz; NH), 7.79 (1H, d, *J* = 6.9 Hz; NH), 7.70 (1H, d, *J* = 6.9 Hz; NH), 7.44-7.23 (31 H, m; ArH, NH), 6.92 (1H, s; NH), 6.69 (1H, d, *J* = 3.9 Hz; 1-OH), 5.68 (1H, s; Ph-CH=O$_2$), 5.30 (1H, t, *J* = 5.7

Hz; -COCH$_2$OH), 5.12-4.98 (7 H, m; -COOCH$_2$Ph × 3, H-1), 4.76-4.71 (2H, m; H-1', Ph-CH-O-), 4.60-4.51 (3H, m; Ph-CH-O- × 3), 4.46 (1H, q, *J* = 6.4 Hz; Lac-αH), 4.39-3.97 (7H, m; D-Ala-αH, Ala-αH, H-6', DAP 2-H, Gln-αH, DAP 6-H, H-3'), 3.80-3.50 (11H, m; H-4, H-6', H-4', H-2, H-2', H-6, H-6, H-3, H-5, -COCH$_2$OH), 3.24-3.18 (1H, m; H-5'), 2.17-2.12 (2H, m; Gln-γCH$_2$), 2.00-1.93 (1H, m; Gln-βCH), 1.83 (3H, s; -NHCOCH$_3$), 1.75-1.34 (5H, m; Gln-βCH, DAP 3-CH$_2$, 5-CH$_2$), 1.26-1.21 (11H, m; DAP 4-CH$_2$, Lac-βCH$_3$, Ala-βCH$_3$, D-Ala-βCH$_3$). HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{80}H_{96}N_8O_{23}Na$: 1559.6481 $[M+Na]^+$; found: 1559.6486.

2-Allyloxycarbonylamino-1,6-anhydro-2-deoxy-4-hydroxyl-3-*O*-[(1*R*)-1-(ethyoxycarbonyl)ethyl]-β-D-glucopyranose (38): Compound **25** (580 mg, 1.537 mmol) and $Pd(OH)_2$ (600 mg, 4.27 mmol) were mixed well in THF (6 mL), and reacted under H_2 atmosphere (1.5 MPa) for 36 h. The $Pd(OH)_2$ was removed by membrane filtration, the filtrate was concentrated in vacuo. Without any further purification, to a solution of the residue in anhydrous CH_2Cl_2 (12 mL) was added triethylamine (320 μL, 2.31 mmol) and then allyl chloroformate (196 μL, 1.84 mmol) at 0 °C under Argon atmosphere. Then the reaction was allowed to react at room temperature for 1.5 h. The reaction was quenched with saturated aq. $NaHCO_3$ and extracted with $CHCl_3$ three times. The combined organic layers were washed with brine, dried over Na_2SO_4, and concentrated in vacuo. The crude compound was purified by silica-gel flash chromatography ($CHCl_3$/MeOH 40:1) to give **38** as a white solid (300 mg, 57%).

^{1}H NMR (500 MHz, $CDCl_3$): *δ* 5.95-5.87 (1H, m; -O-CH$_2$-CH=CH$_2$), 5.57 (1H, d, *J* = 8.5 Hz; NH), 5.41 (1H, s; H-1), 5.31 (1H, d, *J* = 17.2 Hz; -O-CH$_2$-CH=CHH), 5.22 (1H, d, *J* = 10.5 Hz; -O-CH$_2$-CH=CHH), 4.60-4.55 (2H, m; -O-CH$_2$-CH=CH$_2$), 4.52 (1H, d, *J* = 5.3 Hz; H-5), 4.25-4.19 (4H, m; H-6, -COOCH$_2$CH$_3$, Lac-αH), 3.86 (1H, d, *J* = 9.2 Hz; H-2), 3.76 (1H, dd, *J* = 5.9 Hz, 7.2Hz; H-6'), 3.73 (1H, s; H-4), 3.47 (1H, s; H-3), 2.82 (1H, s; OH), 1.42 (3H, d, *J* = 6.8 Hz; Lac-βCH$_3$), 1.28 (3H, t, *J* = 7.2 Hz; -COOCH$_2$CH$_3$). ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 158.1, 144.3, 126.0, 114.2, 100.8, 80.9, 79.3, 75.8, 72.6, 72.1, 68.9, 61.1, 34.4, 31.2, 19.9. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{15}H_{23}NO_8Na$: 368.1316 $[M+Na]^+$; found: 368.1318.

1,6-Anhydro-2-allyloxycarbonylamino-4-*O*-[3'-*O*-benzyl-4',6'-*O*-benzylidene-2'-deoxy-2'-(2,2,2-trichloroethoxy-carbonylamino)-β-D-glucopyranosyl]-2-deoxy-3-*O*-[(*R*)-1-(ethoxyca- rbonyl)ethyl]-D-glucopyranoside (39): Compound **39** was synthesized from **38** and **30** with similar method to the synthesis of **31**. The crude compound was purified by silica-gel flash chromatography (toluene/AcOEt 5:1) to give compound **38** as a white solid (149 mg, 50%).

^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.51-7.29 (10H, m; ArH), 5.98-5.90 (1H, m; -O-CH$_2$-CH=CH$_2$), 5.69 (1H, br s; NH), 5.60 (1H, s, Ph-CH=O$_2$), 5.36-5.32 (2H, m; -O-CH$_2$-

CH=C<u>H</u>H, H_{anh}-1), 5.21 (1H, dd, *J* = 1.3 Hz, 10.5 Hz; -O-CH_2-CH=CH<u>H</u>), 4.99 (1H, d, *J* = 5.9 Hz; N<u>H</u>), 4.91 (1H, d, *J* = 11.9 Hz; Ph-C<u>H</u>-O-), 4.70 (1H, d, *J* = 11.9 Hz; Ph-C<u>H</u>-O-), 4.83-4.80 (2H, m; -O-C<u>H</u>-CCl_3, H-1), 4.61-4.54 (3H, m; -O-C<u>H</u>-CCl_3, -O-C<u>H_2</u>-CH=CH_2), 4.47 (1H, d, *J* = 5.8 Hz; H_{anh}-5), 4.33 (1H, dd, *J* = 4.9 Hz, 10.5 Hz; H-6), 4.24-4.16 (4H, m; -O-C<u>H_2</u>CH_3, Lac-α<u>H</u>, H_{anh}-6), 3.91 (1H, d, *J* = 9.1 Hz; H_{anh}-2), 3.86 (1H, dd, *J* = 9.5 Hz, 9.5 Hz; H-3), 3.81-3.70 (4H, m; H-6', H-4, H_{anh}-6', H_{anh}-4), 3.56 (1H, s; H_{anh}-3), 3.50-3.42 (2H, m; H-2, H-5), 1.41 (3H, d, *J* = 6.9 Hz; Lac-βC<u>H_3</u>), 1.28 (3H, t, *J* = 7.2 Hz; -$COOCH_2C$<u>H_3</u>). ^{13}C NMR (125 MHz, $CDCl_3$): *δ*17 2.5, 155.7, 154.4, 137.8, 137.1, 132.9, 129.1, 128.6, 128.5, 128.4, 128.1, 126.0, 117.6, 101.4, 101.3, 95.4, 82.4, 75.8, 74.9, 74.6, 74.4, 74.3, 68.5, 66.3, 65.6, 64.8, 61.2, 57.7, 51.2, 18.1, 14.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{38}H_{45}Cl_3N_2O_{14}Na$: 883.1809 $[M+Na]^+$; found: 883.1816.

1,6-Anhydro-2-allyloxycarbonylamino-4-*O*-[2'-acetylamino-3'-*O*-benzyl-4',6'-*O*-benzylidene-2'-deoxy-β-D-glucopyranosyl]-2-deoxy-3-*O*-[(*R*)-1-(ethoxycarbonyl)ethyl]-D-glucopyranoside (S16) Compound **S16** was synthesized from **39** with similar method to the synthesis of **S14**. The crude compound was purified by silica-gel flash chromatography (toluene/AcOEt 1:1) to give compound **S16** as a white solid (83 mg, 76%). ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.50-7.30 (10H, m; Ar<u>H</u>), 5.97-5.90 (1H, m; -O-CH_2-C<u>H</u>=CH_2), 5.61-5.58 (2H, m; N<u>H</u>, Ph-C<u>H</u>=O_2), 5.49 (1H, d, *J* = 7.2 Hz; N<u>H</u>), 5.35-5.31 (2H, m; -O-CH_2-CH=C<u>H</u>H, H_{anh}-1), 5.21 (1H, dd, *J* = 1.1 Hz, 10.5 Hz; -O-CH_2-CH=CH<u>H</u>), 5.13 (1H, d, *J* = 8.1 Hz; H-1), 4.90 (1H, d, *J* = 11.9 Hz; Ph-C<u>H</u>-O-), 4.65 (1H, d, *J* = 11.9 Hz; Ph-C<u>H</u>-O-), 4.61-4.54 (2H, m; -O-C<u>H_2</u>-CH=CH_2), 4.45 (1H, d, *J* = 4.6 Hz; H_{anh}-5), 4.33 (1H, dd, *J* = 4.9 Hz, 10.5 Hz; H-6), 4.23-4.13 (5H, m; -O-C<u>H_2</u>CH_3, Lac-α<u>H</u>, H_{anh}-6, H-3), 3.90 (1H, d, *J* = 9.4 Hz; H_{anh}-2), 3.79-3.67 (4H, m; H-6', H-4, H_{anh}-6', H_{anh}-4), 3.55-3.49 (2H, m; H_{anh}-3, H-5), 3.39-3.34 (1H, m; H-2), 1.89 (3H, s; -NHCOC<u>H_3</u>), 1.41 (3H, d, *J* = 6.9 Hz; Lac-βC<u>H_3</u>), 1.28 (3H, t, *J* = 7.2 Hz; -$COOCH_2C$<u>H_3</u>). ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 172.5, 171.0, 155.6, 138.2, 137.2, 132.9, 129.1, 128.5, 128.4, 128.3, 128.0, 126.0, 117.7, 101.3, 101.2, 99.0, 82.6, 76.0, 75.1, 74.5, 74.3, 72.9, 68.6, 66.2, 65.7, 64.9, 61.2, 57.6, 51.1, 23.6, 18.2, 14.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{37}H_{46}N_2O_{13}Na$: 749.2892 $[M+Na]^+$; found: 749.2897.

1,6-Anhydro-2-glycolylamino-4-*O*-[2'-acetylamino-3'-*O*-benzyl-4',6'-*O*-benzylidene-2'-deoxy-β-D-glucopyranosyl]-2-deoxy-3-*O*-[(*R*)-1-(ethoxycarbonyl)ethyl]-D-glucopyranoside (40): Compound **40** was synthesized from **S16** with similar method to the synthesis of **32**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 35:1) to give **40** as a white solid (30 mg, 78 %).

^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.52-7.31 (10H, m; Ar<u>H</u>), 7.01 (1H, d, *J* = 9.3 Hz;

N<u>H</u>), 5.6 (1H, s; Ph-C<u>H</u>=O_2), 5.36-5.33 (2H, m; H_{anh}-1, N<u>H</u>), 4.90 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.67 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.58 (1H, br s; -$COCH_2O$<u>H</u>), 4.53 (1H, d, *J* = 8.5 Hz; H-1), 4.45 (1H, d, *J* = 5.4 Hz; H_{anh}-5), 4.33 (1H, dd, *J* = 4.9 Hz, 10.6 Hz; H-6), 4.25-4.08 (7H, m; -O-C<u>H_2</u>CH_3, Lac-α<u>H</u>, H_{anh}-6, H_{anh}-2, -COC<u>H_2</u>OH), 3.96-3.91 (1H, m; H-2), 3.84-3.71 (4H, m; H-6', H-4, H_{anh}-6', H_{anh}-4), 3.64 (1H, dd, *J* = 9.7 Hz, 9.7 Hz; H-3), 3.50 (1H, s; H_{anh}-3), 3.42-3.37 (1H, m; H-5), 1.91 (3H, s; -NHCOC<u>H_3</u>), 1.40 (3H, d, *J* = 6.8 Hz; Lac-βC<u>H_3</u>), 1.28 (3H, t, *J* = 7.2 Hz; -$COOCH_2C$<u>H_3</u>). ^{13}C NMR (125 MHz, $CDCl_3$): *δ* 172.4, 172.2, 171.9, 138.1, 137.1, 129.1, 128.6, 128.4, 128.2, 126.0, 101.4, 100.9, 99.6, 82.2, 76.2, 74.3, 73.9, 73.3, 72.0, 68.5, 66.5, 64.6, 62.7, 61.3, 55.1, 48.7, 23.5, 18.1, 14.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{35}H_{44}N_2O_{13}Na$: 723.2736 $[M+Na]^+$; found: 723.2740.

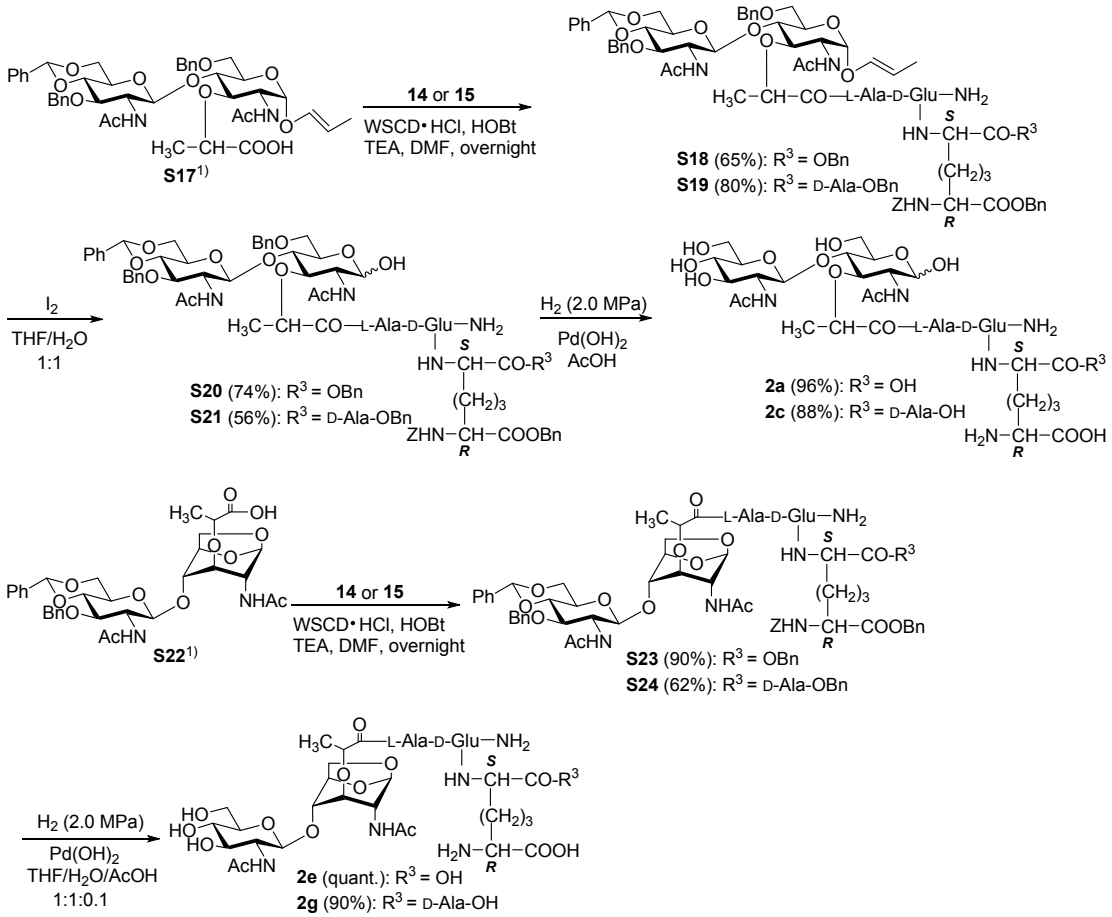
1,6-Anhydro-2-glycolylamino-4-*O*-[2'-acetylamino-3'-*O*-benzyl-4',6'-*O*–benzylidene-2'-deoxy-β-D-glucopyranosyl]-2-deoxy-3-*O*-[(*R*)-1-(carbonyl)ethyl]-D-glucopyranoside (41): Compound **41** was synthesized from **40** with similar method to the synthesis of **18**. Compound **41** was used without further purification.

HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{15}H_{23}NO_8Na$: 368.1316 $[M+Na]^+$; found: 368.1318.

Protected disaccharide (anh) containing *N*-glycolylmuramyl group and tripeptide (42): Compound **42** was synthesized from **41** and **14** with similar method to the synthesis of **19**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give compound **42** as a white solid (19 mg, 70 %). ^{1}H NMR (500 MHz, $CDCl_3$): *δ* 7.83 (1H, *J* = 6.6 Hz; N<u>H</u>), 7.61 (1H, *J* = 6.9 Hz; N<u>H</u>), 7.52-7.31 (26 H, m; Ar<u>H</u>, N<u>H</u>), 7.08 (1H, *J* = 9.2 Hz; N<u>H</u>), 6.73 (1H, s; N<u>H</u>), 5.74 (1H, d, *J* = 8.4 Hz; N<u>H</u>), 5.61 (1H, s; Ph-C<u>H</u>=O_2), 5.40 (1H, s; H_{anh}-1), 5.37 (1H, d, *J* = 8.8 Hz; N<u>H</u>), 5.17-5.05 (6H, m; -$COOCH_2$Ph × 3), 4.91 (1H, d, *J* = 12.2 Hz; Ph-C<u>H</u>-O-), 4.87 (1H, t, *J* = 7.2 Hz; -$NHCOCH_2O$<u>H</u>), 4.71-4.66 (2H, m; Ph-C<u>H</u>-O-, Gln-α<u>H</u>), 4.48-4.44 (3H, m; DAP 2-<u>H</u>, H-1, H_{anh}-5), 4.37-4.26 (4H, m; DAP 6-H, Ala-α<u>H</u>, H-6, H_{anh}-6), 4.21-4.08 (3H, m; Lac-α<u>H</u>, -NHCOC<u>H_2</u>OH), 4.00-3.96 (2H, m; H-2, H_{anh}-2), 3.84-3.72 (4H, m; H-6', H-4, H_{anh}-4, H_{anh}-6'), 3.59 (1H, dd, *J* = 9.3 Hz, 9.3 Hz; H-3), 3.49 (1H, s; H_{anh}-3), 3.41-3.36 (1H, m; H-5), 2.34-2.25 (2H, m; Gln-γC<u>H_2</u>), 2.10-2.05 (1H, m; Gln-βC<u>H</u>), 1.92 (3H, s; -NHCOC<u>H_3</u>), 1.86-1.64 (5H, m; Gln-βC<u>H</u>, DAP 3-C<u>H_2</u>, 5-C<u>H_2</u>), 1.45-1.33 (8H, m; DAP 4-C<u>H_2</u>, Lac-βC<u>H_3</u>, Ala-βC<u>H_3</u>). ^{13}C NMR (125 MHz, $CDCl_3$): *δ*17 3.6, 173.5, 173.4, 173.0, 173.0, 172.9, 172.1, 171.9, 156.2, 138.0, 137.0, 136.2, 135.2, 135.2, 129.2, 128.7, 128.7, 128.6, 128.5, 128.5, 128.4, 128.2, 128.2, 126.0, 101.3, 100.8, 99.6, 82.1, 76.7, 73.8, 73.4, 72.4, 68.5, 67.4, 67.2, 67.1, 67.1, 66.5, 64.7, 62.7, 54.8, 53.7, 52.7, 51.7, 49.5, 47.1, 32.4, 31.8, 30.3, 29.7, 23.5, 21.3, 17.5, 17.2. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{70}H_{83}N_7O_{21}Na$: 1380.5534 $[M+Na]^+$; found: 1380.5540.

Protected disaccharide (anh) containing *N*-glycolylmuramyl group and tetrapeptide (43): Compound **43** was synthesized from **41** and **15** with similar method to the synthesis of **19**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give compound **43** as a white solid (19 mg, 66 %).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.94 (1H, s; NH), 7.54-7.28 (28 H, m; ArH, NH × 3), 7.10 (1H, J = 9.0 Hz; NH), 7.02 (1H, s; NH), 5.75 (1H, d, J = 7.3 Hz; NH), 5.59 (1H, s; Ph-CH=O_2), 5.40 (1H, s; H_{anh}-1), 5.14-5.03 (6H, m; -$COOCH_2$Ph × 3), 4.97 (1H, s; -$NHCOCH_2OH$), 4.90 (1H, d, J = 12.2 Hz; Ph-CH-O-), 4.68 (1H, d, J = 12.2 Hz; Ph-CH-O-), 4.54-4.44 (4H, m; Gln-αH, H_{anh}-5, D-Ala-αH, H-1), 4.33-4.26 (5H, m; Ala-αH, H-6, H_{anh}-6, DAP 2-H, 6-H), 4.19-4.07 (3H, m; Lac-αH, -$NHCOCH_2OH$), 4.00-3.95 (2H, m; H-2, H_{anh}-2), 3.82-3.62 (5H, m; H-6', H-4, H_{anh}-4, H_{anh}-6'), 3.53 (1H, s; H_{anh}-3), 3.41-3.36 (1H, m; H-5), 2.23-2.10 (3H, br m; Gln-γCH_2, Gln-βCH), 1.92 (3H, s; -$NHCOCH_3$), 1.83-1.63 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.45-1.32 (11H, m; DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3, D-Ala-βCH_3). ^{13}C NMR (125 MHz, $CDCl_3$): δ 173.4, 173.3, 173.1, 173.0, 172.9, 172.2, 172.1, 156.2, 138.1, 137.1, 136.3, 135.3, 129.1, 128.7, 128.5, 128.5, 128.3, 128.2, 128.1, 128.0, 126.0, 101.3, 100.8, 99.5, 82.1, 75.5, 73.9, 73.5, 72.4, 68.5, 67.1, 67.0, 66.5, 64.8, 62.7, 54.9, 53.8, 51.5, 48.4, 47.1, 32.1, 32.0, 30.7, 29.7, 23.4, 21.5, 17.5, 17.5, 17.4. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{73}H_{88}N_8O_{22}Na$: 1451.5905 $[M+Na]^+$; found: 1451.5916.



Scheme S4. Preparation of *N*-acetyl disaccharide containing PGN fragments.

Protected disaccharide containing *N*-acetylmuramyl group and tripeptide (S18): Compound **S18** was synthesized from **S17** and **14** with similar method to the synthesis of **S6**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 25:1) to give **S18** as a white solid (32 mg, 65%).

^{1}H NMR (500 MHz, DMSO-d_6): δ 8.27 (1H, d, J = 7.2 Hz; NH), 8.28-8.07 (4H, m; 4NH), 7.75 (1H, d, J = 7.7 Hz; NH), 7.44-7.24 (31H, m; ArH, NH), 6.97 (1H, s; NH), 6.17 (1H, dd, J = 1.3 Hz, 12.2 Hz; -O-CH=CH-CH_3), 5.68 (1H, s; Ph-CH=O_2), 5.20 (1H, d, J = 3.0 Hz; H-1), 5.10-4.98 (7 H, m; -COOCH_2Ph × 3, -O-CH=CH-CH_3), 4.81-4.72 (2H, m; Ph-CH-O-, H-1'), 4.60-4.43 (5H, m; Ph-CH-O- × 3, Lac-αH, Ala-αH), 4.26 (1H, dd, J = 4.9 Hz, 10.2 Hz; H-6'), 4.21-4.17 (2H, m; Gln-αH, DAP 2-H), 4.06-4.00 (2H, m; H-3', DAP 6-H), 3.86-3.20 (10H, m; H-4, H-6', H-4', H-2', H-2, H-5, H-6, H-6, H-3, H-5'), 2.16-2.11 (2H, m; Gln-γCH_2), 1.96-1.89 (1H, m; Gln-βCH), 1.82 (6H, s; -NHCOCH_3 × 2), 1.74-1.56 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.45 (3H, dd, J = 1.3 Hz, 6.9 Hz; -O-CH=CH-CH_3), 1.35 (2H, br s; DAP 4-CH_2), 1.26-1.20 (6H, m; Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (125 MHz, DMSO-d_6): δ 174.0, 173.1, 173.0, 172.1, 172.0, 171.9, 171.8, 169.7, 156.1, 143.6, 138.7, 138.5, 137.6, 136.8, 135.9, 135.9, 128.4, 128.3, 128.2, 128.1, 128.1, 128.0, 128.0, 127.8, 127.7,

127.7, 127.4, 127.3, 127.2, 127.1, 126.0, 103.3, 103.3, 100.2, 95.7, 81.3, 77.5, 75.3, 75.0, 73.5, 71.7, 67.7, 65.9, 65.8, 65.5, 65.4, 53.8, 53.4, 52.0, 48.0, 31.4, 30.2, 30.2, 27.9, 22.9, 22.7, 21.9, 19.6, 18.9, 12.2. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{80}H_{95}N_7O_{21}Na$: 1512.6473 $[M+Na]^+$; found: 1512.6466.

Protected disaccharide containing *N*-acetylmuramyl group and tetrapeptide (S19): Compound **S19** was synthesized from **S17** and **15** with similar method to the synthesis of **S6**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 25:1) to give **S19** as a white solid (31 mg, 80%).

^{1}H NMR (500 MHz, DMSO-d_6): δ 8.54 (1H, d, J = 5.0 Hz; NH), 8.33 (4H, d, J = 7.1 Hz; NH), 8.24-8.17 (2H, m; 2NH), 8.09 (1H, d, J = 6.5 Hz; NH), 7.88 (1H, d, J = 8.0 Hz; NH), 7.70 (1H, d, J = 7.9 Hz; NH), 7.44-7.24 (31H, m; ArH, NH), 6.93 (1H, s; NH), 6.17 (1H, d, J = 12.5 Hz; -O-CH=CH-CH_3), 5.68 (1H, s; Ph-CH=O_2), 5.20 (1H, s; H-1), 5.10-4.98 (7 H, m; -COOCH_2Ph × 3, -O-CH=CH-CH_3), 4.81-4.71 (2H, m; Ph-CH-O-, H-1'), 4.60-4.41 (5H, m; Ph-CH-O- × 3, Lac-αH, D-Ala-αH), 4.31-3.98 (6H, m; H-6', Gln-αH, Ala-αH, DAP 2-H, H-3', DAP 6-H), 3.86-3.20 (10H, m; H-4, H-6', H-4', H-2', H-2, H-5, H-6, H-6, H-3, H-5'), 2.17-2.10 (2H, m; Gln-γCH_2), 1.99-1.92 (1H, m; Gln-βCH), 1.82 (6H, s; -NHCOCH_3 × 2), 1.74-1.45 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.45 (3H, d, J = 6.8 Hz; -O-CH=CH-CH_3), 1.37-1.22 (11H, m; DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3, D-Ala-βCH_3). HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{83}H_{100}N_8O_{22}Na$: 1583.6844 $[M+Na]^+$; found: 1583.6852.

1-*O*-Deprotected disaccharide containing *N*-acetylmuramyl group and tripeptide (S20): Compound **S20** was synthesized from **S18** with similar method to the synthesis of **S8**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 25:1) to give compound **S20** as white solid (20 mg, 74 %).

^{1}H NMR (500 MHz, DMSO-d_6): δ 8.41 (1 H, d, J = 5.3 Hz; NH), 8.30-8.25 (2 H, m; 2NH), 8.19 (1 H, d, J = 8.0 Hz; NH), 8.04 (1 H, d, J = 6.4 Hz; NH), 7.75 (1 H, d, J = 7.5 Hz; NH), 7.44-7.23 (31 H, m; ArH, NH), 6.96 (1 H, s; NH), 6.62 (1 H, d, J = 3.8 Hz; 1-OH), 5.68 (1H, s; Ph-CH=O_2), 5.13-4.98 (7 H, m; -COOCH_2Ph × 3, H-1), 4.74-4.72 (2H, m; Ph-CH-O-, H-1'), 4.61-4.38 (5H, m; Ph-CH-O- × 3, Lac-αH, Ala-αH), 4.26 (1H, dd, J = 4.5 Hz, 9.6 Hz; H-6'), 4.21-4.14 (2H, m; Gln-αH, DAP 2-H), 4.04-4.00 (2H, m; H-3', DAP 6-H), 3.76-3.20 (10H, m; H-4, H-6', H-4', H-2', H-2, H-5, H-6, H-6, H-3, H-5'), 2.16-2.13 (2H, m; Gln-γCH_2), 1.95-1.89 (1H, m; Gln-βCH), 1.83 (3H, s; -NHCOCH_3), 1.80 (3H, s; -NHCOCH_3), 1.76-1.56 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.35 (2H, br s; DAP 4-CH_2), 1.25-1.21 (6H, m; Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (125 MHz, DMSO-d_6): δ 174.1, 173.1, 172.1, 172.0, 172.0, 171.8, 169.4, 156.2, 138.8, 138.6, 137.6, 136.8, 135.9, 135.9, 128.8, 128.4, 128.3, 128.2, 128.1, 128.1, 128.0, 128.0, 127.9, 127.8, 127.7, 127.7, 127.4, 127.3, 127.2, 126.0, 100.2, 89.7, 81.3, 76.0, 75.8, 75.2, 73.5, 71.7, 69.7, 68.2, 68.0, 66.3, 65.9, 65.8, 65.5,

65.4, 54.3, 53.8, 52.2, 52.0, 48.2, 31.5, 30.2, 30.2, 27.8, 22.9, 22.8, 22.0, 19.6, 18.6. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{77}H_{91}N_7O_{21}Na$: 1472.6160 $[M+Na]^+$; found: 1472.6172.

1-*O*-Deprotected disaccharide containing *N*-acetylmuramyl group and tetrapeptide (S21) Compound **S21** was synthesized from **S19** with similar method to the synthesis of **S8**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 25:1) to give **S21** as a white solid (13 mg, 56 %).

^{1}H NMR (500 MHz, DMSO-d_6): δ 8.38 (1H, d, J = 5.6 Hz; NH), 8.33 (1H, d, J = 7.1 Hz; NH), 8.23 (1 H, d, J = 8.1 Hz; NH), 8.16 (1H, d, J = 8.7 Hz; NH), 8.00 (1H, d, J = 7.3 Hz; NH), 7.88 (1 H, d, J = 8.3 Hz; NH), 7.70 (1H, d, J = 7.4 Hz; NH),7.44-7.22 (31 H, m; ArH, NH), 6.91 (1 H, s; NH), 6.59 (1H, d, J = 4.3 Hz; 1-OH), 5.68 (1H, s; Ph-CH=O_2), 5.14-4.98 (7 H, m; -COOCH_2Ph × 3, H-1), 4.75-4.72 (2H, m; Ph-CH-O-, H-1'), 4.61-4.38 (5H, m; Ph-CH-O- × 3, Lac-αH, D-Ala-αH), 4.30-3.98(6H, m; Ala-αH, H-6', Gln-αH, DAP 2-H, H-3', DAP 6-H), 3.76-3.20 (10H, m; H-4, H-6', H-4', H-2', H-2, H-5, H-6, H-6, H-3, H-5'), 2.21-2.09 (2H, m; Gln-γCH_2), 1.99-1.93 (1H, m; Gln-βCH), 1.83 (3H, s; -NHCOCH_3), 1.80 (3H, s; -NHCOCH_3), 1.74-1.56 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.45-1.23 (11H, m; DAP 4-CH_2, D-Ala-βCH_3, Lac-βCH_3, Ala-βCH_3). HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{80}H_{96}N_8O_{22}Na$: 1543.6531 $[M+Na]^+$; found: 1543.6533.

Compounds **2a** and **2c** were synthesized from **S20** and **S21**, respectively, with similar method to the synthesis of **1b**.

Compound **2a** (yield 96% from **S20**): ^{1}H NMR (500 MHz, D_2O): δ 5.17 (0.74 H, d, J = 5.7 Hz; H-1β), 4.57 (0.26 H, d, J = 8.3 Hz; H-1α), 4.50-4.45 (2H, m; H-1', Lac-αH), 4.31-4.19 (3H, m; Ala-αH, DAP 2-H, Gln-αH), 3.88-3.61 (9H, m; H-6, H-6', H-2, H-6, H-2', H-5', H-6', H-3, DAP 6-H), 3.54-3.33 (4H, m; H-4', H-4, H-5, H-3'), 2.35-2.32 (2H, m; Gln-γCH_2), 2.15-2.08 (1H, m; Gln-βCH), 1.98 (3H, s; -NHCOCH_3), 1.90 (3H, s; -NHCOCH_3), 2.01-1.65 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.45-1.36 (5H, m; DAP 4-CH_2, Ala-βCH_3), 1.33 (3H, d, J = 6.8 Hz; Lac-βCH_3). ^{13}C NMR (125 MHz, D_2O): δ 178.6, 176.9, 176.5, 175.9, 175.6, 175.5, 175.4, 175.0, 101.3, 91.2, 80.3, 78.9, 78.4, 77.0, 76.4, 74.5, 72.0, 71.2, 62.0, 60.7, 56.9, 55.4, 54.5, 53.8, 50.8, 32.6, 31.7, 30.9, 28.0, 23.0, 23.0, 22.0, 19.1, 17.6. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{34}H_{58}N7O_{19}$: 868.3782 $[M+H]^+$; found: 868.3796.

Compound **2c** (yield 88% from **S21**): ^{1}H NMR (700 MHz, D_2O): δ 5.15 (0.56 H, d, J = 3.5 Hz; H-1β), 4.49-4.44 (2H, m; H-1', Lac-αH), 4.30-4.20 (3H, m; D-Ala-αH, Ala-αH, Gln-αH), 4.08-4.05 (1H, m; DAP 2-H), 3.86 (1H, dd, J = 4.2 Hz, 11.2 Hz; H-6), 3.81-3.60 (8H, m; H-6', H-2, H-6, H-2', H-5', H-6', H-3, DAP 6-H), 3.53-3.46 (2H, m; H-4', H-4), 3.35-3.32 (2H, m; H-5, H-3'), 2.35-2.32 (2H, m; Gln-γCH_2), 2.11-2.06 (1H, m; Gln-βCH), 1.97 (3H, s; -NHCOCH_3), 1.89 (3H, s; -NHCOCH_3), 1.99-1.64

(5H, m; Gln-βC<u>H</u>, DAP 3-C<u>H</u>$_2$, 5-C<u>H</u>$_2$), 1.38-1.23 (11H, m; DAP 4-C<u>H</u>$_2$, D-Ala-βC<u>H</u>$_3$, Ala-βC<u>H</u>$_3$, Lac-βC<u>H</u>$_3$). ^{13}C NMR (176 MHz, D_2O): δ 179.7, 175.9, 175.7, 175.0, 175.0, 174.7, 174.2, 172.9, 100.4, 90.3, 79.4, 78.0, 77.5, 76.1, 75.5, 73.6, 71.1, 70.3, 61.2, 59.8, 56.1, 54.5, 53.9, 52.9, 51.0, 50.0, 31.6, 30.9, 30.1, 27.1, 22.2, 22.1, 21.1, 18.2, 17.6, 16.7. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{37}H_{62}N_8O_{20}Na$: 961.3973 $[M+Na]^+$; found: 961.3978.

Protected disaccharide (anh) containing *N*-acetylmuramyl group and tripeptide (S23): Compound **S23** was synthesized from **S22** and **14** with similar method to the synthesis of **S6**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 15:1) to give **S23** as a white solid (22 mg, 90 %). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85 (1H, d, J = 5.7 Hz; N<u>H</u>), 7.59 (1H, d, J = 7.3 Hz; N<u>H</u>), 7.52-7.29 (26 H, m; Ar<u>H</u>, N<u>H</u>), 6.93 (1H, d, J = 9.8 Hz; N<u>H</u>), 6.76 (1H, s; N<u>H</u>), 5.73 (1H, d, J = 8.2 Hz; N<u>H</u>), 5.60 (1H, s; Ph-C<u>H</u>=O$_2$), 5.47 (1H, s; N<u>H</u>), 5.31 (1H, s; H_{anh}-1), 5.21 (1H, d, J = 8.5 Hz; N<u>H</u>), 5.17-5.04 (6H, m; -COOC<u>H</u>$_2$Ph × 3), 4.91 (1H, d, J = 12.4 Hz; Ph-C<u>H</u>-O-), 4.69-4.66 (2H, m; Ph-C<u>H</u>-O-, Gln-α<u>H</u>), 4.50-4.25 (7H, m; DAP 2-<u>H</u>, 6-<u>H</u>, H_{anh}-5, H-1, H-6, H_{anh}-6, Ala-α<u>H</u>), 4.12-3.97 (3H, m; Lac-α<u>H</u>, H-2, H_{anh}-2), 3.84-3.78 (2H, m; H-6', H-4), 3.76 (1H, d, J = 2.1 Hz; H_{anh}-4), 3.70 (1H, dd, J = 5.7 Hz, 7.3 Hz; H_{anh}-6'), 3.55 (1H, dd, J = 9.6 Hz, 9.6 Hz; H-3), 3.47 (1H, s; H_{anh}-3), 3.41-3.35 (1H, m; H-5), 2.35-2.25 (2H, m; Gln-γC<u>H</u>$_2$), 2.11-2.05 (4H, m; NHCOC<u>H</u>$_3$, Gln-βC<u>H</u>), 1.91 (3H, s; -NHCOC<u>H</u>$_3$), 1.97-1.69 (5H, m; Gln-βC<u>H</u>, DAP 3-C<u>H</u>$_2$, 5-C<u>H</u>$_2$), 1.46-1.39 (2H, m; DAP 4-C<u>H</u>$_2$), 1.35-1.33 (6H, m; Lac-βC<u>H</u>$_3$, Ala-βC<u>H</u>$_3$). ^{13}C NMR (125 MHz, $CDCl_3$): δ 173.8, 173.5, 173.1, 173.0, 172.2, 171.6, 171.2, 156.2, 138.1, 137.1, 136.2, 135.3, 135.2, 129.1, 128.7, 128.6, 128.6, 128.5, 128.5, 128.3, 128.2, 126.0, 101.3, 101.3, 100.2, 82.0, 77.7, 76.4, 75.5, 73.8, 72.4, 68.5, 67.3, 67.1, 67.1, 67.0, 66.4, 64.4, 54.7, 53.7, 52.7, 51.8, 49.6, 46.9, 32.4, 31.7, 30.6, 29.7, 23.7, 22.8, 21.4, 17.4, 17.2. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{70}H_{84}N_7O_{20}$: 1342.5766 $[M+H]^+$; found: 1342.5790.

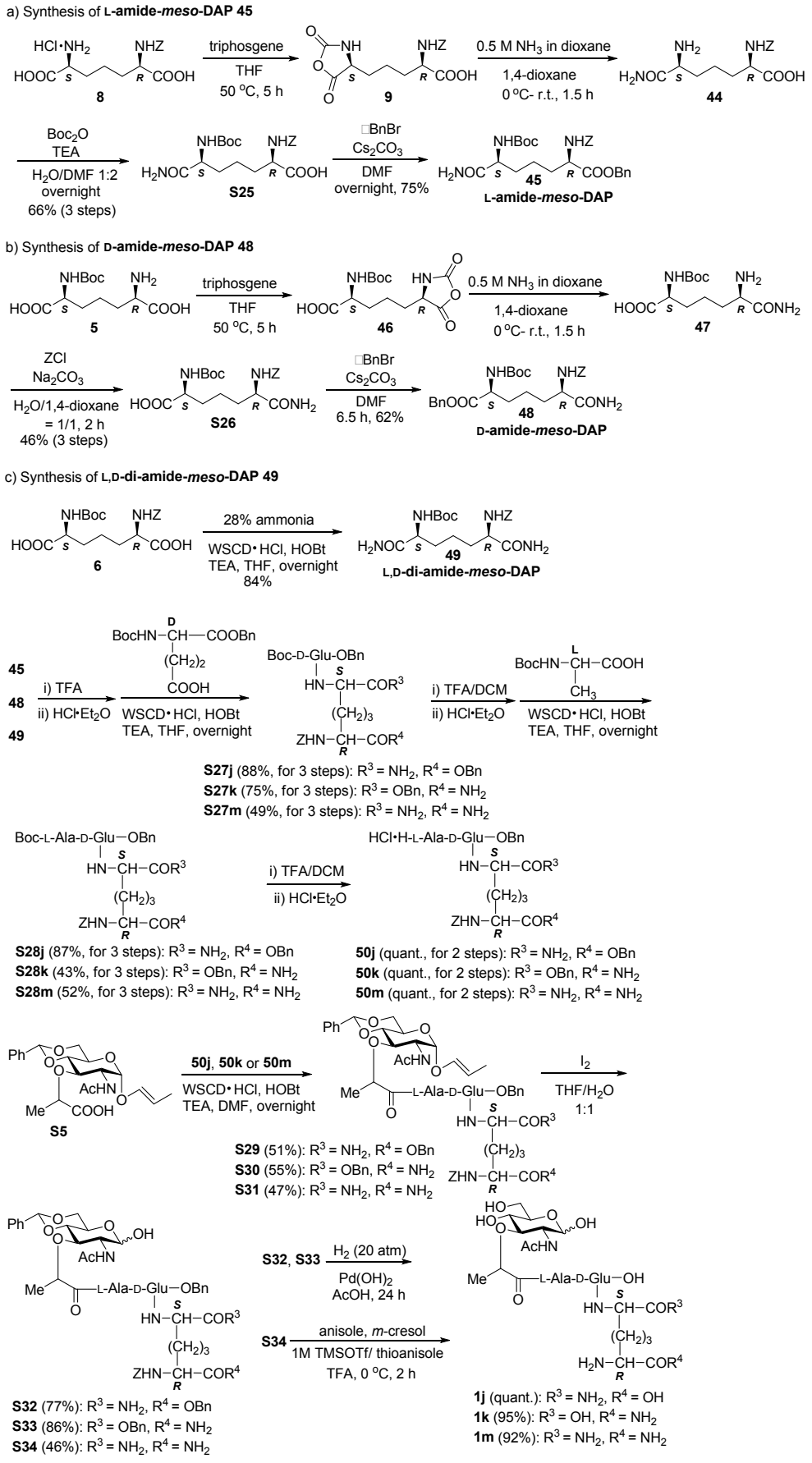
Protected disaccharide (anh) containing *N*-acetylmuramyl group and tetrapeptide (S24): Compound **S24** was synthesized from **S22** and **15** with similar method to the synthesis of **S6**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give **S24** as a white solid (16 mg, 62 %). ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.88 (1H, br s; N<u>H</u>), 7.62 (1H,br s; N<u>H</u>), 7.54-7.28 (26 H, m; Ar<u>H</u>, N<u>H</u>), 7.03 (1H, br s; N<u>H</u>), 6.96 (1H, s; N<u>H</u>), 6.93 (1H, s; N<u>H</u>), 5.73 (1H, d, J = 7.2 Hz; N<u>H</u>), 5.60 (1H, s; Ph-C<u>H</u>=O$_2$), 5.31 (1H, s; H_{anh}-1), 5.14-5.04 (6H, m; -COOC<u>H</u>$_2$Ph × 3), 4.91 (1H, d, J = 12.3 Hz; Ph-C<u>H</u>-O-), 4.68 (1H, d, J = 12.3 Hz; Ph-C<u>H</u>-O-), 4.53-4.25 (9H, m; Gln-α<u>H</u>, DAP 2-<u>H</u>, 6-<u>H</u>, H_{anh}-5, H-1, H-6, H_{anh}-6, Ala-α<u>H</u>, D-Ala-α<u>H</u>), 4.11-3.99 (3H, m; Lac-α<u>H</u>, H-2, H_{anh}-2), 3.84-3.75 (3H, m; H-6', H-4, H_{anh}-4), 3.71 (1H, dd, J = 7.1 Hz, 7.1 Hz; H_{anh}-6'), 3.55 (1H, dd, J = 9.2 Hz, 9.2 Hz;

H-3), 3.47 (1H, s; H_{anh}-3), 3.40-3.35 (1H, m; H-5), 2.25 (2H, br s; Gln-γC$\underline{H}_2$), 2.11-2.06 (4H, m; -NHCOC$\underline{H}_3$, Gln-βC$\underline{H}$), 1.91 (3H, s; -NHCOC$\underline{H}_3$), 1.87-1.62 (5H, m; Gln-βC$\underline{H}$, DAP 3-C$\underline{H}_2$, 5-C$\underline{H}_2$), 1.46-1.32 (11H, m; DAP 4-C$\underline{H}_2$, Lac-βC$\underline{H}_3$, Ala-βC$\underline{H}_3$, D-Ala-βC$\underline{H}_3$). ^{13}C NMR (125 MHz, $CDCl_3$): δ 173.8, 173.6, 173.5, 173.3, 172.2, 171.7, 171.2, 156.2, 138.1, 137.2, 136.3, 135.3, 129.1, 128.7, 128.6, 128.5, 128.4, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 126.0, 101.3, 101.3, 100.2, 82.1, 75.4, 73.9, 72.4, 68.5, 67.2, 67.0, 66.4, 64.5, 54.7, 53.8, 51.6, 49.7, 48.4, 47.0, 32.0, 30.7, 29.7, 23.7, 22.8, 21.5, 17.4, 17.4, 17.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{73}H_{88}N_8O_{21}Na$: 1435.5956 $[M+Na]^+$; found: 1435.5973.

Compounds **2e** and **2g** were synthesized from **S23** and **S24**, respectively, with the similar method to the synthesis of **1f**.

Compound **2e** (yield quant. from **S23**): ^{1}H NMR (500 MHz, CD_3OD): δ 5.32 (1H, s; H_{anh}-1), 4.61 (1H, d, J = 4.5 Hz; H_{anh}-5), 4.49 (1H, d, J = 8.4 Hz; H-1), 4.40-4.28 (4H, m; Ala-α$\underline{H}$, Gln-α$\underline{H}$, DAP 2-$\underline{H}$, H_{anh}-6), 4.11 (1H, q, J = 6.7 Hz; Lac-α$\underline{H}$), 4.04 (1H, s; H_{anh}-2), 3.89 (1H, dd, J = 1.9 Hz, 11.9 Hz; H-6), 3.85 (1H, s; H_{anh}-4), 3.78-3.67 (4H, m; H-2, H-5, DAP 6-$\underline{H}$, H_{anh}-6'), 3.53 (1H, s; H_{anh}-3), 3.46-3.42 (1H, m; H-3), 3.34-3.27 (2H, m; H-6', H-4), 2.37-2.34 (2H, m; Gln-γC$\underline{H}_2$), 2.21-2.15 (1H, m; Gln-βC$\underline{H}$), 2.06 (3H, s; -NHCOC$\underline{H}_3$), 2.02 (3H, s; -NHCOC$\underline{H}_3$), 1.99-1.70 (5H, m; Gln-βC$\underline{H}$, DAP 3-C$\underline{H}_2$, 5-C$\underline{H}_2$), 1.56-1.51 (2H, m; DAP 4-C$\underline{H}_2$), 1.41 (3H, d, J = 7.0 Hz; Ala-βC$\underline{H}_3$), 1.36 (3H, d, J = 6.7 Hz; Lac-βC$\underline{H}_3$). ^{13}C NMR (125 MHz, D_2O): δ 176.9, 176.9, 176.7, 176.4, 176.1, 176.0, 174.6, 174.6, 101.6, 100.9, 78.2, 77.0, 75.3, 74.6, 74.3, 70.8, 65.8, 62.5, 61.6, 56.5, 54.8, 53.8, 53.8, 50.6, 49.9, 32.4, 31.1, 30.7, 27.7, 23.3, 22.9, 21.9, 19.0, 17.6. HRMS (LTQ-orbitrap MS): m/z: calcd for $C_{34}H_{55}N_7O_{18}Na$: 872.3496 $[M+Na]^+$; found: 872.3507.

Compound **2g** (yield 90% from **S24**): ^{1}H NMR (500 MHz, D_2O): δ 5.38 (1H, s; H_{anh}-1), 4.65-4.59 (2H, m; H_{anh}-5, H-1), 4.29 (1H, q, J = 7.5 Hz; D-Ala-α$\underline{H}$), 4.24-4.15 (4H, m; Ala-α$\underline{H}$, Gln-α$\underline{H}$, DAP 2-$\underline{H}$, H_{anh}-6), 4.11 (1H, q, J = 7.5 Hz; Lac-α$\underline{H}$), 3.94 (1H, s; H_{anh}-2), 3.91 (1H, s; H_{anh}-4), 3.85-3.82 (1H, m; H-6), 3.76-3.65 (4H, m; H_{anh}-6', DAP 6-$\underline{H}$, H-5, H-2), 3.52-3.49 (2H, m; H_{anh}-3, H-3), 3.40-3.38 (2H, m; H-6, H-4), 2.36-2.32 (2H, m; Gln-γC$\underline{H}_2$), 2.17-2.10 (1H, m; Gln-βC$\underline{H}$), 2.00 (3H, s; -NHCOC$\underline{H}_3$), 1.99 (3H, s; -NHCOC$\underline{H}_3$), 1.95-1.66 (5H, m; Gln-βC$\underline{H}$, DAP 3-C$\underline{H}_2$, 5-C$\underline{H}_2$), 1.42-1.36 (5H, m; DAP 4-C$\underline{H}_2$, D-Ala-βC$\underline{H}_3$), 1.31 (6H, m; Ala-βC$\underline{H}_3$, Lac-βC$\underline{H}_3$). ^{13}C NMR (125 MHz, D_2O): δ 179.3, 176.8, 176.6, 176.3, 176.0, 176.0, 175.4, 174.6, 174.2, 101.6, 100.9, 78.2, 77.0, 75.4, 74.6, 74.3, 70.8, 65.8, 61.6, 56.5, 55.4, 54.8, 53.8, 51.0, 50.6, 49.9, 32.5, 31.8, 31.0, 27.8, 23.3, 22.9, 22.0, 19.0, 18.0, 17.7. HRMS (LTQ-orbitrap MS): m/z: calcd for $C_{37}H_{60}N_8O_{19}Na$: 943.3867 $[M+Na]^+$; found: 943.3876.



Scheme S5. Preparation of PGN fragments with amidated *meso*-DAP.

7-amino-(2*R*,6*S*)-2-(((benzyloxy)carbonyl)amino)-6-((*tert*-butoxycarbonyl)amino)-7-oxoheptanoic acid (S25): Compound **8** (80 mg, 0.222 mmol) was dissolve in dry THF at 50 °C, followed by addition of triphosgene (73 mg, 0.246 mmol) in dry THF. The clear solution was reacted at 50 °C for 5 h. After cooling to room temperature, the solvent was evaporated quickly, the oily solid **9** was washed by dry hexane twice. Without purification, the next step was proceeded immediately.

The above compound **9** was dissolved in dry 1,4-dioxane (4 mL) at 0 °C, then 0.5 M ammonia solution in 1,4-dioxane (2 mL) was added at 0 °C. The mixture was allowed to react at 0 °C for 30 min to give **44**. After removing solvent, the next step was proceeded directly.

Compound **44** was dissolved in H_2O/ DMF (1:2, 7.5 mL), and triethylamine (0.37 mL) was added at 0 °C. Di-*tert*-butyl dicarbonate (0.92 mL) was dropped into the solution. The solution was reacted at room temperature overnight. Then it was acidified to pH 2-3 and extracted with ethyl acetate three times, dried over Na_2SO_4 and concentrated in vacuo. The crude compound was purified by silica-gel flash chromatography, eluted with $CHCl_3$:MeOH:CH_3COOH = 15:1:0.1 to give the pure **S25** (62 mg, 66% for 3 steps). ^{1}H NMR (400 MHz, CD_3OD): δ 7.37-7.26 (5H, m; Ar<u>H</u>), 5.16-5.04 (2H, m; -O-C<u>H</u>$_2$-Ph), 4.13 (1H, dd, J = 4.8 Hz, 8.9 Hz; -C<u>H</u>(NHZ)-), 4.00 (1H, dd, J = 4.6 Hz, 8.5 Hz; -C<u>H</u>(NHBoc)-), 1.91-1.43 (15H, m; DAP 3-C<u>H</u>$_2$, 4-C<u>H</u>$_2$, 5-C<u>H</u>$_2$, -OC(C<u>H</u>$_3$)$_3$). ^{13}C NMR (100 MHz, CD_3OD): δ 177.8, 176.1, 158.7, 157.9, 138.2, 129.5, 129.0, 128.8, 80.6, 67.6, 55.6, 55.4, 33.1, 32.5, 28.7, 23.4. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{20}H_{29}N_3O_7Na$: 446.1898 $[M+Na]^+$; found: 446.1906.

7-amino-benzyl-(2*R*,6*S*)-2-[{(benzyloxy)carbonyl}amino]-6-{(*tert*-butoxycarbony)amino}-7-oxoheptanoate (L-amide-*meso*-DAP) (45): Compound **S25** (55 mg, 0.13 mmol) and cesium carbonate (25 mg, 0.077 mmol) were stirred in dry DMF (6 mL) for 20 min, benzyl bromide (14 μL, 0.116 mmol) was then added to the reacting flask at 0 °C, stirred at 0 °C for 1h, and then reacted at room temperature overnight. The reaction was quenched by addition of water and extracted with ethyl acetate three times, dried over Na_2SO_4 and concentrated in vacuo. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$:CH_3OH = 35:1) to give **45** as a white solid (36.5 mg, 55%).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36-7.29 (10H, m; Ar<u>H</u>), 6.10 (1H, s; N<u>H</u>), 5.47 (1H, d, J = 7.6 Hz; N<u>H</u>), 5.41 (1H, s; N<u>H</u>), 5.21-5.06 (5H, m; -O-C<u>H</u>$_2$-Ph × 2, N<u>H</u>), 4.40 (1H, d, J = 6.2 Hz; -C<u>H</u>(NHBoc)-), 4.05 (1H, s; -C<u>H</u>(NHZ)-), 1.83-1.39 (15H, m; DAP 3-C<u>H</u>$_2$, 4-C<u>H</u>$_2$, 5-C<u>H</u>$_2$, -OC(C<u>H</u>$_3$)$_3$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 174.2, 172.1, 156.0, 155.8, 136.2, 135.3, 128.7, 128.6, 128.4, 128.2, 128.1, 80.2, 67.2, 67.1, 53.6, 53.4, 32.2, 31.8, 28.3, 21.2. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{27}H_{35}N_3O_7Na$: 536.2367

$[M+Na]^+$; found: 536.2375.

7-amino-(2*S*,6*R*)-6-[{(benzyloxy)carbonyl}amino]-2-{(*tert*-butoxycarbonyl)amino}-7-oxoheptanoic acid (S26): Compound **5** (34 mg, 0.117 mmol) was dissolve in dry THF at 50 °C, followed by addition of triphosgene (38 mg, 0.129 mmol) in dry THF. The clear solution was reacted at 50 °C for 5 h. After cooling to room temperature, the solvent was evaporated quickly, the oily solid **46** was washed by dry hexane twice. Without purification, the next step was proceeded immediately. The above compound **46** was dissolved in dry 1,4-dioxane (4 mL) at 0 °C, then 0.5 M ammonia solution in 1,4-dioxane (1.2 mL) was added at 0 °C. The mixture was allowed to react at 0 °C for 30 min to give **47**. After removing solvent, the next step was proceeded directly. Compound **S26** was synthesized from **47** with similar method to the synthesis of **S25**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$:CH_3OH:CH_3COOH = 15:1:0.1) to give **S26** as a white solid (100 mg, 46% for 3 steps). ^{1}H NMR (400 MHz, CD_3OD): δ 7.36-7.26 (5H, m; Ar<u>H</u>), 5.12-5.04 (2H, m; -O-C<u>H</u>$_2$-Ph), 4.09-4.01 (2H, m; -C<u>H</u>(NHBoc)-, -C<u>H</u>(NHZ)-), 1.83-1.42 (15H, m; DAP 3-C<u>H</u>$_2$, 4-C<u>H</u>$_2$, 5-C<u>H</u>$_2$, -OC(C<u>H</u>$_3$)$_3$). ^{13}C NMR (100 MHz, CD_3OD): δ 177.7, 177.4, 158.5, 158.1, 138.1, 129.5, 129.0, 128.9, 80.4, 67.7, 55.1, 33.0, 32.8, 28.7, 23.3. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{20}H_{29}N_3O_7Na$: 446.1898 $[M+Na]^+$; found: 446.1904.

7-amino-benzyl-(2*S*,6*R*)-6-[{(benzyloxy)carbonyl}amino]-2-{(*tert*-butoxycarbonyl)amino}-7-oxoheptanoate (D-amide-*meso*-DAP) (48): Compound **48** was synthesized from **S26** with similar method to the synthesis of **45**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 30:1) to give **48** as a white solid (70 mg, 62%).

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38-7.26 (10H, m; Ar<u>H</u>), 6.11 (1H, s; N<u>H</u>), 5.40 (1H, s; N<u>H</u>), 5.32 (1H, s; N<u>H</u>), 5.21-5.10 (5H, m; -O-C<u>H</u>$_2$-Ph × 2, N<u>H</u>), 4.33 (1H, d, J = 5.9 Hz; -C<u>H</u>(NHBoc)-), 4.14 (1H, d, J = 4.8 Hz; -C<u>H</u>(NHZ)-), 1.88-1.38 (15H, m; DAP 3-C<u>H</u>$_2$, 4-C<u>H</u>$_2$, 5-C<u>H</u>$_2$, -OC(C<u>H</u>$_3$)$_3$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.6, 172.4, 156.3, 155.6, 136.2, 135.3, 128.7, 128.6, 128.4, 128.2, 128.1, 127.8, 80.2, 67.2, 54.1, 52.7, 32.4, 31.7, 28.3, 21.2. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{27}H_{35}N_3O_7Na$: 536.2367 $[M+Na]^+$; found: 536.2375.

(2*S*,6*R*)-2-[{(benzyloxy)carbonyl}amino]-6-{(*tert*-butoxycarbonyl)amino}-heptanediamide (L,D-di-amide-*meso*-DAP) (49): Compound **49** was synthesized from **6** and 28% ammonia solution with similar method to the synthesis of **S6**. The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 15:1) to give **49** as a white solid (67 mg, 84%).

^{1}H NMR (400 MHz, CD_3OD): δ 7.28-7.17 (5H, m; Ar<u>H</u>), 5.02-4.96 (2H, m; -O-C<u>H</u>$_2$-Ph), 3.99 (1H, dd, J = 5.0 Hz, 9.0 Hz; -C<u>H</u>(NHBoc)-), 3.90 (1H, dd, J = 4.6 Hz, 8.0 Hz; -C<u>H</u>(NHZ)-), 1.70-1.34 (15H, m; DAP 3-C<u>H</u>$_2$, 4-C<u>H</u>$_2$, 5-C<u>H</u>$_2$, -OC(C<u>H</u>$_3$)$_3$). ^{13}C

NMR (100 MHz, CD_3OD): δ 177.8, 177.5, 158.5, 157.9, 138.1, 129.5, 129.0, 128.9, 80.6, 67.7, 56.1, 55.6, 33.1, 33.0, 28.7, 23.4. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{20}H_{30}N_4O_6Na$: 445.2058 $[M+Na]^+$; found: 445.2075.

The Boc group of **43**, **46**, or **47** was deprotected with TFA, the liberated amino group was then coupled with Boc-D-Glu-OBn to generate compounds **S27j**, **S27k** or **S27m** with similar method to the synthesis of **12**.

Fully protected D-isoGlu-*meso*-DAP(L-amide) (S27j): The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 30:1) to give **S27j** (100 mg, 88%). ^1H NMR (500 MHz, $CDCl_3$): δ 7.37-7.26 (15H, m; ArH), 6.63 (1H, s; NH), 6.36 (1H, d, J = 5.4 Hz; NH), 5.49 (1H, d, J = 6.9 Hz; NH), 5.35-5.33 (2H, m; NH × 2), 5.19-5.06 (6H, m; -O-CH_2-Ph × 3), 4.39-4.33 (3H, m; DAP 2-H, 6-H, Glu-αH), 2.27-2.22 (3H, m; Gln-γCH_2, Gln-βCH), 1.88-1.59 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.41 (11H, br s; DAP 4-CH_2, -OC(CH_3)$_3$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.8, 172.2, 172.1, 172.0, 156.1, 155.9, 136.2, 135.2, 128.7, 128.6, 128.6, 128.5, 128.3, 128.2, 128.0, 80.3, 67.3, 67.1, 53.4, 52.7, 52.5, 32.3, 31.9, 31.0, 28.8, 28.3, 21.2. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{39}H_{48}N_4O_{10}Na$: 755.3263 $[M+Na]^+$; found: 755.3271.

Fully protected D-isoGlu-*meso*-DAP(D-amide) (S27k): The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 35:1) to give **S27k** (64 mg, 75%). ^1H NMR (500 MHz, $CDCl_3$): δ 7.40-7.31 (15H, m; ArH), 6.56 (1H, s; NH), 6.44 (1H, s; NH), 5.50 (1H, s; NH), 5.33 (2H, br s; NH × 2), 5.25-5.07 (H, m; -O-CH_2-Ph × 3), 4.62 (1H, dd, J = 7.8 Hz, 13.2 Hz; DAP 2-H), 4.35 (1H, d, J = 6.2 Hz; Glu-αH), 4.17 (1H, d, J = 6.1 Hz; DAP 6-H), 2.32-2.20 (2H, m; Gln-γCH_2), 2.10-2.00 (2H, m; Gln-βCH_2), 1.88-1.58 (4H, m; DAP 3-CH_2, 5-CH_2), 1.41 (11H, br s; DAP 4-CH_2, -OC(CH_3)$_3$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.7, 172.3, 172.1, 171.7, 156.3, 155.7, 136.3, 135.3, 128.7, 128.6, 128.5, 128.5, 128.3, 128.2, 128.0, 80.3, 67.2, 67.0, 53.9, 52.8, 51.5, 32.2, 32.1, 31.7, 28.8, 28.3, 21.2. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{39}H_{48}N_4O_{10}Na$: 755.3263 $[M+Na]^+$; found: 755.3283.

Fully protected D-isoGlu-*meso*-DAP(L,D-di-amide) (S27m): The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 17:1) to give **S27m** (126 mg, 49%). ^1H NMR (400 MHz, DMSO-d_6): δ 7.81 (1H, d, J = 8.0 Hz; NH), 7.34-7.26 (13H, m; ArH, NH × 3), 7.20 (1H, d, J = 8.2 Hz; NH), 6.93 (2H, s; NH × 2), 5.15-4.97 (4H, m; -O-CH_2-Ph × 2), 4.12 (1H, dd, J = 7.3 Hz, 13.3 Hz; DAP 2-H), 3.99 (1H, dd, J = 8.7 Hz, 13.1 Hz; Glu-αH), 3.87 (1H, dd, J = 8.2 Hz, 13.1 Hz; DAP 6-H), 2.22-2.19 (2H, m; Gln-γCH_2), 1.99-1.91 (1H, m; Gln-βCH), 1.79-1.70 (1H, m; Gln-βCH), 1.65-1.43 (4H, m; DAP 3-CH_2, 5-CH_2), 1.36-1.26 (11H, m; DAP 4-CH_2, -OC(CH_3)$_3$). ^{13}C NMR (100 MHz, DMSO-d_6): δ 173.8, 173.6, 172.2, 171.1, 155.9, 155.5, 137.0, 135.9, 128.3, 128.2, 127.9, 127.6, 127.6, 78.2, 65.7, 65.3, 54.4, 53.4, 52.2, 31.7, 31.5, 28.1, 26.5, 21.9. HRMS (ESI-LIT-orbitrap): m/z: calcd for

$C_{32}H_{43}N_5O_9Na$: 664.2953 $[M+Na]^+$; found: 664.2968.

Compounds **S28j**, **S28k** and **S28m** were synthesized by coupling Boc-L-Ala-OH with compounds **S27j**, **S27k** and **S27m**, respectively, with similar method to the synthesis of **12**.

Fully protected L-Ala-D-isoGlu-*meso*-DAP(L-amide) (S28j): The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 30:1) to give **S28j** (81 mg, 87%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33-7.26 (15H, m; ArH), 7.22 (1H, d, J = 8.0 Hz; NH), 6.89 (1H, s; NH), 5.56 (1H, d, J = 7.6 Hz; NH), 5.49 (1H, s; NH), 5.17-5.05 (7H, m; -O-CH_2-Ph × 3, NH), 4.48 (1H, s; Glu-αH), 4.37-4.29 (2H, m; DAP 2-H, 6-H), 4.10 (1H, t, J = 6.6 Hz; Ala-αH), 2.26-2.13 (2H, m; Gln-γCH_2), 1.93-1.67 (6H, m; Gln-βCH_2, DAP 3-CH_2, 5-CH_2), 1.48-1.41 (11H, br s; DAP 4-CH_2, -OC(CH_3)$_3$), 1.29 (3H, d, J = 7.1 Hz; Ala-βCH_3). ^{13}C NMR (100 MHz, $CDCl_3$): δ 174.5, 173.4, 172.4, 172.1, 171.6, 156.1, 155.8, 136.2, 135.3, 135.3, 128.7, 128.6, 128.6, 128.5, 128.3, 128.2, 128.1, 80.7, 67.3, 67.2, 67.1, 53.6, 53.2, 51.0, 32.0, 31.5, 31.0, 28.3, 27.6, 21.5, 17.9. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{42}H_{53}N_5O_{11}Na$: 826.3634 $[M+Na]^+$; found: 826.3646.

Fully protected L-Ala-D-isoGlu-*meso*-DAP(D-amide) (S28k): The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 35:1) to give **S28k** (26 mg, 43%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.40-7.30 (15H, m; ArH), 7.13 (1H, s; NH), 7.02 (1H, s; NH), 6.41 (1H, s; NH), 5.57 (1H, s; NH), 5.25-5.10 (6H, m; -O-CH_2-Ph × 3), 4.61-4.56 (2H, m; DAP 2-H, Glu-αH), 4.14 (2H, s; Ala-αH, DAP 6-H), 2.23 (3H, br s; Gln-γCH_2, βCH), 1.89-1.56 (5H, m; DAP 3-CH_2, 5-CH_2, βCH), 1.47-1.42 (11H, m; DAP 4-CH_2, -OC(CH_3)$_3$), 1.28 (3H, d, J = 6.7 Hz; Ala-βCH_3). ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.4, 173.9, 172.4, 172.1, 170.7, 156.9, 156.2, 136.2, 135.3, 128.9, 128.8, 128.7, 128.6, 128.3, 128.1, 80.5, 67.4, 67.2, 67.1, 54.1, 52.3, 51.8, 51.5, 32.1, 31.8, 31.2, 28.3, 21.4, 20.9. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{42}H_{53}N_5O_{11}Na$: 826.3634 $[M+Na]^+$; found: 826.3646.

Fully protected L-Ala-D-isoGlu-*meso*-DAP(L,D-di-amide) (S28m): The crude compound was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 15:1) to give **S28m** (64 mg, 52%). ^{1}H NMR (400 MHz, DMSO-d_6): δ 8.21 (1H, d, J = 7.8 Hz; NH), 7.81 (1H, d, J = 8.0 Hz; NH), 7.38-7.27 (10H, m; ArH), 6.94 (1H, s; NH), 6.80 (1H, d, J = 7.1 Hz; NH), 5.15-4.97 (4H, m; -O-CH_2-Ph × 2), 4.26 (1H, dd, J = 5.0 Hz, 9.2 Hz; Glu-αH), 4.12-4.09 (1H, m; DAP 2-H), 4.03-4.00 (1H, m; Ala-αH), 3.86 (1H, dd, J = 5.0 Hz, 8.9 Hz; DAP 6-H), 2.19-2.15 (2H, m; Gln-γCH_2), 2.04-1.95 (1H, m; Gln-βCH), 1.85-1.76 (1H, m; Gln-βCH), 1.66-1.41 (4H, m; DAP 3-CH_2, 5-CH_2), 1.36-1.23 (11H, m; DAP 4-CH_2, -OC(CH_3)$_3$), 1.17 (3H, d, J = 7.1 Hz; Ala-βCH_3). ^{13}C NMR (100 MHz, DMSO-d_6): δ 173.7, 173.5, 172.9, 171.5, 171.0, 155.8, 154.9, 137.0, 135.8, 128.3, 128.2, 127.9, 127.7, 127.6, 78.0, 65.9, 65.3, 54.4, 52.1, 51.5, 49.6, 31.6, 31.2, 28.1,

27.9, 26.8, 21.9, 18.4. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{35}H_{48}N_6O_{10}Na$: 735.3324 $[M+Na]^+$; found: 735.3320.

Protected H-L-Ala-D-isoGlu-*meso*-DAP(L-amide) (50j), H-L-Ala-D-isoGlu-*meso*-DAP(D-amide) (50k), H-L-Ala-D-isoGln-*meso*-DAP(L,D-amide) (50m)

Compounds **50j**, **50k and 50m** were synthesized from compounds **S28j**, **S28k** and **S28m** respectively with similar method to the synthesis of **14**. The compounds were used without further purification.

Protected monosaccharide containing *N*-acetylmuramyl group and tripeptide (S29): Compound **S29** was synthesized from **S5** and **50j** with similar method to the synthesis of **S6**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 30:1) to give **S29** as a white solid (46 mg, 51%).

^{1}H NMR (400 MHz, DMSO-d_6): δ 8.39 (1H, d, J = 7.3 Hz; NH), 8.16 (1H, d, J = 7.8 Hz; NH), 7.75 (1H, d, J = 8.0 Hz; NH), 7.66 (1H, d, J = 7.8 Hz; NH), 7.50 (1H, d, J = 7.8 Hz; NH), 7.36-7.22 (20 H, m; ArH), 6.88 (1H, s; NH), 6.14 (1H, d, J = 12.4 Hz; -O-CH=CH-), 5.63 (1H, s; Ph-CH=O_2), 5.03-4.91 (8H, m; -O-CH=CH-, H-1, -CH_2Ph × 3), 4.31-4.11 (3H, m; Ala-αH, Gln-αH, Lac-αH), 4.08-3.91 (4H, m; DAP 2-H, 6-H, H-2, H-4), 3.73-3.58 (4H, m; H-5, H-3, H-6, H-6'), 2.13-2.09 (2H, m; Gln-γCH_2), 1.97-1.91 (1H, m; Gln-βCH), 1.74 (3H, s; -NHCOCH_3), 1.75-1.50 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.43 (3H, d, J = 6.0 Hz; -CH=CH-CH_3), 1.26-1.14 (8H, m; DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (100 MHz, DMSO-d_6): δ 173.5, 172.2, 171.7, 171.4, 170.9, 169.7, 156.1, 143.5, 137.4, 136.8, 135.9, 135.8, 128.7, 128.4, 128.3, 128.1, 127.9, 127.8, 127.6, 125.9, 104.1, 100.3, 97.0, 80.6, 76.7, 75.6, 67.8, 65.9, 65.8, 65.5, 63.1, 54.0, 52.8, 52.0, 51.7, 47.7, 31.4, 31.2, 30.3, 26.8, 22.5, 21.9, 18.9, 18.9, 12.1. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{58}H_{71}N_6O_{16}$: 1107.4921 $[M+H]^+$; found: 1107.4941.

Protected monosaccharide containing *N*-acetylmuramyl group and tripeptide (S30): Compound **S30** was synthesized from **S5** and **50k** with similar method to the synthesis of **S6**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 30:1) to give **S30** as a white solid (19 mg, 55%).

^{1}H NMR (400 MHz, DMSO-d_6): δ 8.45 (1H, d, J = 7.6 Hz; NH), 8.22 (1H, d, J = 7.6 Hz; NH), 7.56 (1H, d, J = 8.0 Hz; NH), 7.44-7.19 (20 H, m; ArH), 7.20 (1H, d, J = 8.2 Hz; NH), 6.94 (1H, s; NH), 6.21 (1H, dd, J = 1.6 Hz, 12.4 Hz; -O-CH=CH-), 5.70 (1H, s; Ph-CH=O_2), 5.11-5.00 (8H, m; -O-CH=CH-, H-1, -CH_2Ph × 3), 4.38-4.11 (5H, m; Ala-αH, Gln-αH, Lac-αH, DAP 2-H, 6-H,), 4.02-3.64 (6H, m; H-2, H-4, H-5, H-3, H-6, H-6'), 2.20-2.16 (2H, m; Gln-γCH_2), 2.01-1.93 (1H, m; Gln-βCH), 1.80 (3H, s; -NHCOCH_3), 1.83-1.55 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.49 (3H, dd, J = 1.6 Hz, 6.9 Hz; -CH=CH-CH_3), 1.37-1.20 (8H, m; DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3).

HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{58}H_{71}N_6O_{16}$: 1107.4921 $[M+H]^+$; found: 1107.4941.

Protected monosaccharide containing *N*-acetylmuramyl group and tripeptide (S31): Compound **S31** was synthesized from **S5** and **50m** with similar method to the synthesis of **S6**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 30:1) to give **S31** as a white solid (26 mg, 47%).

^{1}H NMR (400 MHz, DMSO-d_6): δ 8.45 (1H, d, J = 7.6 Hz; NH), 8.22 (1H, d, J = 7.8 Hz; NH), 7.82 (1H, d, J = 8.0 Hz; NH), 7.56 (1H, d, J = 7.8 Hz; NH), 7.44-7.26 (18 H, m; ArH, NH × 3), 7.20 (1H, d, J = 8.2 Hz; NH), 6.92 (1H, s; NH), 6.21 (1H, dd, J = 1.6 Hz, 12.4 Hz; -O-CH=CH-), 5.71 (1H, s; Ph-CH=O_2), 5.11-4.96 (6H, m; -O-CH=CH-, H-1, -CH_2Ph × 2), 4.39-4.09 (5H, m; Ala-αH, Gln-αH, Lac-αH, DAP 2-H, 6-H,), 4.02-3.62 (6H, m; H-2, H-4, H-5, H-3, H-6, H-6'), 2.20-2.16 (2H, m; Gln-γCH_2), 2.04-1.96 (1H, m; Gln-βCH), 1.81 (3H, s; -NHCOCH_3), 1.77-1.56 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.50 (3H, dd, J = 1.4 Hz, 6.9 Hz; -CH=CH-CH_3), 1.35-1.20 (8H, m; DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (100 MHz, DMSO-d_6): δ 173.8, 173.6, 172.2, 171.7, 171.4, 170.9, 169.7, 155.9, 143.5, 137.4, 137.0, 135.8, 128.7, 128.3, 128.2, 128.0, 127.9, 127.6, 127.6, 125.9, 104.1, 100.3, 97.0, 80.5, 76.7, 75.6, 67.7, 65.9, 65.3, 63.1, 54.4, 52.8, 52.2, 51.7, 47.6, 31.7, 31.2, 26.8, 22.5, 21.9, 18.9, 18.9, 12.0. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{51}H_{66}N_7O_{15}$: 1016.4611 $[M+H]^+$; found: 1016.4623.

1-*O*-Deprotected monosaccharide containing *N*-acetylmuramyl group and tripeptide (S32): Compound **S32** was synthesized from **S29** with similar method to the synthesis of **S8**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 15:1) to give **S32** as a white solid (24 mg, 77%).

^{1}H NMR (400 MHz, DMSO-d_6): δ 8.44 (1H, d, J = 8.0 Hz; NH), 8.06 (1H, d, J = 8.3 Hz; NH), 7.82 (1H, d, J = 7.8 Hz; NH), 7.72 (1H, d, J = 7.6 Hz; NH), 7.51 (1H, d, J = 7.8 Hz; NH), 7.44-7.28 (21 H, m; ArH, NH), 6.94 (1H, s; NH), 6.90 (1H, d, J = 4.6 Hz; 1-OH), 5.68 (1H, s; Ph-CH=O_2), 5.12-4.98 (7H, m; H-1, -CH_2Ph × 3), 4.38-3.96 (6H, m; Ala-αH, Gln-αH, DAP 2-H, 6-H, Lac-αH, H-6), 3.90-3.60 (5H, m; H-2, H-3, H-4, H-5, H-6), 2.20-2.16 (2H, m; Gln-γCH_2), 2.04-1.93 (1H, br s; Gln-βCH), 1.79 (3H, s; -NHCOCH_3), 1.77-1.57 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.37-1.19 (8H, m; Lac-βCH_3, Ala-βCH_3, DAP 4-CH_2). ^{13}C NMR (100 MHz, DMSO-d_6): δ 173.5, 172.2, 171.7, 171.5, 170.9, 169.5, 156.1, 137.7, 136.8, 135.9, 135.8, 128.7, 128.4, 128.3, 128.0, 127.9, 127.8, 127.7, 127.6, 125.9, 125.8, 100.3, 91.4, 81.2, 76.7, 75.8, 68.1, 65.9, 65.8, 65.5, 62.1, 54.0, 53.7, 52.0, 51.6, 47.6, 31.4, 31.2, 30.3, 26.8, 22.6, 21.9, 18.9, 18.9. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{55}H_{66}N_6O_{16}Na$: 1089.4428 $[M+Na]^+$; found: 1089.4437.

1-*O*-Deprotected monosaccharide containing *N*-acetylmuramyl group and

tripeptide (S33): Compound **S33** was synthesized from **S30** with similar method to the synthesis of **S8**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 20:1) to give **S33** as a white solid (14 mg, 86%).
^{1}H NMR (400 MHz, DMSO-d_6): δ 8.44 (1H, d, J = 7.6 Hz; NH), 8.23 (1H, d, J = 7.4 Hz; NH), 8.06 (1H, d, J = 8.0 Hz; NH), 7.51 (1H, d, J = 8.0 Hz; NH), 7.44-7.27 (21 H, m; ArH, NH), 6.95 (1H, s; NH), 6.90 (1H, d, J = 3.9 Hz; 1-OH), 5.68 (1H, s; Ph-CH=O_2), 5.09-5.00 (7H, m; H-1, -CH_2Ph × 3), 4.39-4.11 (5H, m; Ala-αH, Gln-αH, DAP 2-H, Lac-αH, H-6), 3.89-3.85 (3H, m; DAP 6-H, H-2, H-5), 3.76-3.61 (3H, m; H-3, H-4, H-6'), 2.20-2.16 (2H, m; Gln-γCH_2), 2.00-1.95 (1H, br s; Gln-βCH), 1.79 (3H, s; -NHCOCH_3), 1.84-1.47 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.37-1.19 (8H, m; Lac-βCH_3, Ala-βCH_3, DAP 4-CH_2). ^{13}C NMR (100 MHz, DMSO-d_6): δ 173.7, 172.2, 171.9, 171.7, 171.4, 169.5, 155.9, 137.7, 137.0, 135.9, 135.8, 128.7, 128.3, 128.2, 128.0, 127.9, 127.7, 127.6, 125.9, 100.3, 91.4, 81.2, 76.7, 75.8, 68.1, 65.9, 65.7, 65.3, 62.1, 54.1, 53.7, 52.1, 51.7, 47.6, 31.4, 31.1, 30.4, 26.8, 22.6, 21.9, 18.9, 18.9. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{55}H_{66}N_6O_{16}Na$: 1089.4428 $[M+Na]^+$; found: 1089.4437.
1-*O*-Deprotected monosaccharide containing *N*-acetylmuramyl group and tripeptide (S34): Compound **S34** was synthesized from **S31** with similar method to the synthesis of **S8**. The crude product was purified by silica-gel flash column chromatography ($CHCl_3$/MeOH 7:1) to give **S34** as a white solid (14 mg, 46%).
^{1}H NMR (500 MHz, DMSO-d_6): δ 8.45 (1H, d, J = 7.7 Hz; NH), 8.06 (1H, d, J = 8.2 Hz; NH), 7.83 (1H, d, J = 8.2 Hz; NH), 7.51 (1H, d, J = 7.9 Hz; NH), 7.44-7.21 (16 H, m; ArH, NH), 6.93 (1H, s; NH), 6.90 (1H, d, J = 3.7 Hz; 1-OH), 5.68 (1H, s; Ph-CH=O_2), 5.09-5.00 (5H, m; H-1, -CH_2Ph × 3), 4.36-4.05 (6H, m; Ala-αH, Gln-αH, DAP 2-H, 6-H, Lac-αH, H-6), 3.91-3.84 (2H, m; H-2, H-5), 3.76-3.59 (3H, m; H-3, H-4, H-6'), 2.19-2.16 (2H, m; Gln-γCH_2), 2.03-1.96 (1H, br s; Gln-βCH), 1.79 (3H, s; -NHCOCH_3), 1.76-1.42 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.37-1.19 (8H, m; Lac-βCH_3, Ala-βCH_3, DAP 4-CH_2). HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{48}H_{61}N_7O_{15}Na$: 998.4118 $[M+Na]^+$; found: 998.4130.
Monosaccharide containing *N*-acetylmuramyl group and tripeptide (1j) and (1k) Compounds **1j** and **1k** were synthesized from **S32** and **S33** respectively, with similar method to the synthesis of **1b**.
Compound **1j** (yield quant. from **S32**): ^{1}H NMR (700 MHz, D_2O): δ 5.13 (1H, d, J = 3.6 Hz; H-1β), 4.64 (1H, d, J = 8.4 Hz; H-1α), 4.28-4.20 (4H, m; Ala-αH, Gln-αH, Lac-αH, DAP 2-H), 3.94-3.64 (5H, m; H-2, H-3, H-5, H-6, DAP 6-H), 3.62-3.48 (2H, m; H-4, H-6'), 2.34-2.30 (2H, m; Gln-γCH_2), 2.16-2.12 (1H, m; Gln-βCH), 1.95 (3H, s; -NHCOCH_3), 1.94-1.69 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.47-1.35 (8H, DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (176 MHz, D_2O): δ 176.9, 176.1, 175.5,

174.4, 174.4, 174.3, 174.0, 91.0, 79.6, 77.8, 77.5, 71.6, 69.9, 61.5, 60.8, 53.5, 53.1, 49.8, 31.5, 30.6, 29.9, 27.2, 22.1, 21.0, 18.7, 16.9. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{26}H_{44}N_6O_{14}Na$: 687.2808 $[M+Na]^+$; found: 687.2817.

Compound **1k** (yield 95% from **S33**): ^{1}H NMR (400 MHz, D_2O): δ 5.09 (1H, d, J = 3.2 Hz; H-1β), 4.25-4.15 (4H, m; Ala-αH, Gln-αH, Lac-αH, DAP 2-H), 3.96-3.41 (7H, m; H-2, H-3, H-5, H-6, DAP 6-H, H-4, H-6'), 2.27-2.23 (2H, m; Gln-γCH_2), 2.06 (1H, br s; Gln-βCH), 1.90 (3H, s; -NHCOCH_3), 1.86-1.64 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.43-1.30 (8H, DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3). ^{13}C NMR (100 MHz, D_2O): δ 176.7, 176.4, 175.6, 174.9, 174.9, 174.7, 172.3, 91.6, 80.2, 78.4, 76.4, 72.2, 69.7, 61.5, 61.2, 54.4, 53.5, 50.3, 32.6, 31.4, 31.0, 28.3, 22.7, 21.5, 19.3, 17.6. HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{26}H_{44}N_6O_{14}Na$: 687.2808 $[M+Na]^+$; found: 687.2814.

Monosaccharide containing *N*-acetylmuramyl group and tripeptide (1m): To compound **S34** (0.8 mg, 0.00082 mmol) was added *m*-cresol (8.6 μL, 0.082 mmol) and anisole (2.7 μL, 0.025 mmol) at room temperature under Argon atmosphere. TMSOTf (4.5 μL, 0.025 mmol), thioanisole (2.9 μL, 0.025 mmol) and TFA (25 μL) were then added sequentially at 0 °C to the reaction mixture, and resulting solution was allowed to react at 0 °C for 2 h. After that time, the mixture was washed by hexane and diethylether before adding water. The water solution was neutralized with pyridine and concentrated in vacuo. The residue was resuspended with ultrapure H_2O and lyophilized to give **1m** as a pale white solid (0.5 mg, 92%).

^{1}H NMR (500 MHz, D_2O): δ 5.08 (1H, d, J = 3.3 Hz; H-1β), 4.23-4.11 (4H, m; Ala-αH, Gln-αH, Lac-αH, DAP 2-H), 3.92-3.37 (7H, m; H-2, H-3, H-5, H-6, DAP 6-H, H-4, H-6'), 2.25-2.22 (2H, m; Gln-γCH_2), 2.08-2.00 (1H, br s; Gln-βCH), 1.90 (3H, s; -NHCOCH_3), 1.86-1.64 (5H, m; Gln-βCH, DAP 3-CH_2, 5-CH_2), 1.45-1.31 (8H, DAP 4-CH_2, Lac-βCH_3, Ala-βCH_3). HRMS (ESI-LIT-orbitrap): m/z: calcd for $C_{26}H_{45}N_7O_{13}Na$: 686.2968 $[M+Na]^+$; found: 686.2976.