Synthesis of Muramyl Peptides Containing *meso*-Diaminopimelic Acid

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Chain-extension of L-glutamate aldehyde **3** by means of the Wittig–Horner reaction furnished the desired C_7 dicarboxylic acid derivative, which in turn, after C-C double bond hydrogenation and protecting group manipulation, afforded the 2,6-diaminopimelic acid derivatives (*S*,*R*)-**9** and (*S*,*S*)-**9**, both with the desired orthogonal protecting group pattern. Synthesis of the muramic acid derivative **15** and attachment of an L-alanine residue furnished muramyl-L-alanine **18**. The corresponding 1,6-anhydromuramic acid derivative **26** was obtained similarly. Treatment of these compounds with peptides **28**–**30** and with the 2,6-diaminopimelic acid containing di- and tripeptides **32a**, **32b**, and **35** gave the protected muramyl peptides **17**, **37**, **40**, **42**, **44**, **46**, and **49a** and **49b**, which, after deprotection, afforded the desired target molecules muramyl-L-alanine (**38**), muramyl-L-alanyl-D-glutamic acid (**39**), muramyl-L-alanyl-D-glutaminide (**41**), muramyl-L-alanyl-D-isoglutaminyl-L-lysine (**43**), muramyl-L-alanyl-D-isoglutaminyl-(2*S*,6*R*)-2,6-diaminopimelic acid (**45**), muramyl-L-alanyl-L-isoglutaminyl-(2*S*,6*R*)-2,6-diaminopimelinyl-D-alanine (**47**), 1,6-anhydromuramyl-L-alanyl-D-isoglutaminyl-(2*S*,6*R*)-2,6-diaminopimelic acid (**50a**), and 1,6-anhydromuramyl-L-alanyl-D-isoglutaminyl-(2*S*,6*S*)-2,6-diaminiopimelic acid (**50b**).

Introduction

Bacterial peptidoglycan is a giant macromolecule consisting of linear heteroglycan chains cross-linked by short peptide chains (Figure 1, **A**).[1−3] The heteroglycan chains are composed of alternating β(1−4)-linked *N*-acetylglucosamine (GlcNAc) and *N*-acetylmuramic acid (MurNAc) residues. The carboxyl group of the MurNAc residue has a peptide moiety attached to it. In nascent peptidoglycans this is composed of L-alanyl-γ-D-isoglutaminyl-(α)-(2*S*,6*R*)-2,6-diaminopimelyl (or L-lysyl)-D-alanyl-D-alanine (Figure 1, **B**); however, in mature peptidoglycans one or both D-alanine residues are lost. Neighboring peptidoglycan chains are interlinked either by direct peptide linkages between a diamino acid and a D-alanine residue or by an additional short peptide chain between the diamino acid and the D-alanine residue (see AA_n in Figure 1). The biosynthesis of MurNAc[4] and of the bacterial peptidoglycan has been studied extensively,[5−7] and the availability of the enzymes has resulted in the chemoenzymatic synthesis of biosynthetic intermediates α-linked through the anomeric center of MurNAc to UDP.[8−15]

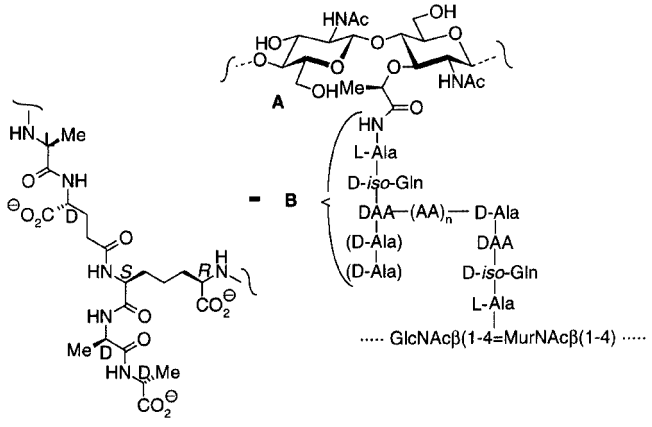

Figure 1. Typical primary structure of bacterial peptidoglycan (**A**); structure of the pentapeptide fragment (**B**); DAA = diamino acid [generally *meso*-diaminopimelic acid (as shown in **B**) or L-lysine]; $(AA)_n$ = *n* amino acids, with $n = 0-5$

Potent cell wall biosynthesis inhibitors have been successfully used for the treatment of bacterial infections for more than fifty years.[16,17] The antibacterial activity of β-lactams and also of glycopeptide antibiotics (such as, for instance, vancomycin) — the most widely used compounds — is due to inhibition of key steps in cell wall biosynthesis.[5−7] However, the emergence of bacterial resistance to these antibiotics is a good reason to investigate the effects of partial structures of peptidoglycans further.[18,19]

Bacterial infections result in an immune response that starts with the production of proinflammatory mediators such as cytokines TNF-α and interleukins-1 and -6.[20,21] Activation of the immune system by Gram-negative bacteria is mainly caused by lipopolysaccharides (LPS) and muramyl peptides, which seem to have a synergistic effect.[22,23] In order to investigate this effect, pure muramyl peptides with different lengths of peptide chain are required. These, however, are not readily available from natural material. Several chemical syntheses of muramyl pep-

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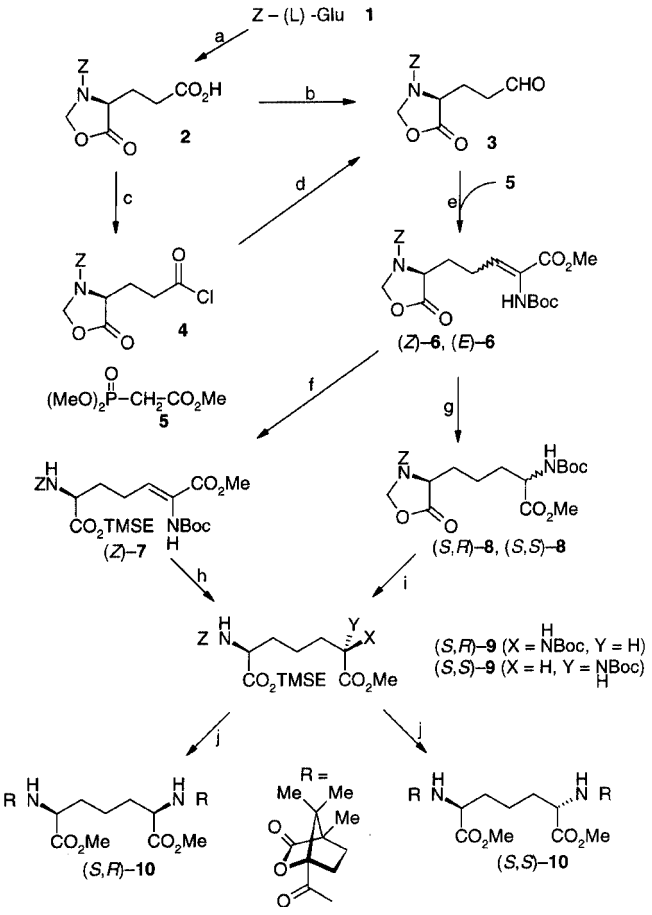
tides and of peptidoglycan di-, tetra-, and octasaccharide fragments containing amino acids up to the dipeptide moiety have been reported.[24−37] The particular target compounds in this paper are muramyl tri- and tetrapeptides containing, for the first time, *meso*-2,6-diaminopimelic acid (Dap[38]) as a cross-linker in the peptidoglycan network. The synthesis of the corresponding 1,6-anhydromuramyl derivatives[39] — products of lytic transglycosidase in the process of cell growth — is also reported.[40] These compounds also exhibit somnogenic properties.[41]

Results and Discussion

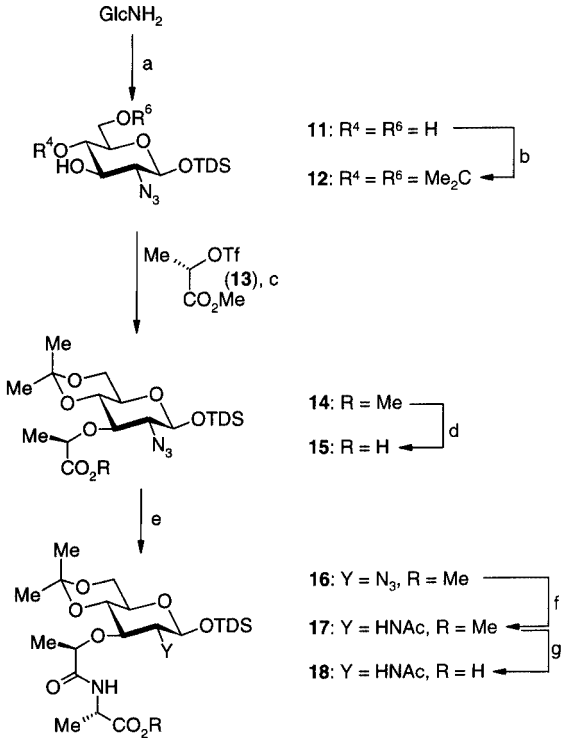
In the muramyl pentapeptide, *meso*-2,6-diaminopimelic acid (Dap) is interlinked through the *S*-configured moiety, while the amino group of the *R*-configured moiety serves as the linker to another muramyl peptide chain. Therefore, an orthogonally protected (2*S*,6*R*)-2,6-diaminopimelic acid that has lost its *meso* stereochemistry is required. For this purpose, a method reported in a preliminary form by Holcomb et al.[42] was essentially followed (Scheme 1). This method requires the catalytic hydrogenation of a C_7-acrylate intermediate obtained from L-glutamate and a C_2-building block. To this end, Z-protected *N*-benzyloxycarbonyl-L-glutamate (**1**) was transformed into the oxazolidinone **2**, which furnished aldehyde **3** after reduction of the carboxylate group and periodinane[43] oxidation of the alcohol intermediate. This compound could also be obtained in the same overall yield by transformation of **2** into the acid chloride **4** with thionyl chloride and subsequent reduction with $LiAl(OtBu)_3H$.[44] A Wittig−Horner reaction with the phosphoryl glycine derivative **5**[45] in the presence of potassium hexamethyldisilazane (KHMDS) as base afforded a 6.3:1 mixture of (*Z*)- and (*E*)-**6**. Asymmetric hydrogenation of (*Z*)-**6** with a rhodium catalyst and (*S*,*S*)-chiraphos provided only a 3:1 mixture of (*S*,*R*)- and (*S*,*S*)-**8**.[42] Therefore, a simple catalytic hydrogenation with Wilkinson's catalyst was performed, affording a 3:2 mixture of (*S*,*R*)- and (*S*,*S*)-**8** in 90% yield. Treatment of this mixture with trimethylsilylethanol in the presence of LiHMDS as base afforded the desired target molecules (*S*,*R*)- and (*S*,*S*)-**9**, which could readily be separated by medium-pressure liquid chromatography (MPLC) with toluene/ethyl acetate (5:1) as eluent. Alternatively, treatment of, for instance, (*Z*)-**6** with trimethylsilylethanol [→ (*Z*)-**7**] and subsequent hydrogenation as described above furnished a 1:1 mixture of (*S*,*R*)- and (*S*,*S*)-**9**, although less of the desired (*S*,*R*)-**9** was obtained by this route. The relative stereochemistries of (*S*,*R*)-**9** and (*S*,*S*)-**9** could readily be confirmed by acid-catalyzed removal of the TMSE, *N*-Boc, and *N*-Z protecting groups, followed by camphanoylation of the amino groups and methyl ester formation: the methyl esters of (*S*,*R*)-**10** are diastereotopic, while those of (*S*,*S*)-**10** are homotopic, and this could be confirmed by the observation of two separate ^1H NMR signals for (*S*,*R*)-**10** and only one ^1H NMR signal for (*S*,*S*)-**10**.[46] These results also indicated that no racemization of the L-glutamate-derived part of the molecule had occurred during the various manipulations.



Scheme 1. Synthesis of diaminopimelic acid derivatives (*S*,*R*)-**9** and (*S*,*S*)-**9**; a) $(CH_2O)_n$, toluene, Δ (86%); b) $BH_3{\cdot}SMe_2$, 0 °C → room temp.; periodinane, room temp. (53%); c) $SOCl_2$, Δ (76%); d) $LiAl(OtBu)_3H$, THF, −78 °C (73%); e) KHMDS, THF, −78 °C → −30 °C [88%, (*Z*)-**6**:(*E*)-**6** = 6.3:1]; f) $Me_3Si{-}CH_2{-}CH_2OH$, LiHMDS, THF, 0 °C (65%); g) $[RhCl(PPh_3)_3]$, H_2, MeOH [90%, (*S*,*R*)-**8**:(*S*,*S*)-**8** = 3:2]; h) $Pd(OH)_2$/C, H_2, MeOH; Z-Cl, $NaHCO_3$, THF/H_2O [70%, (*S*,*R*)-**9**:(*S*,*S*)-**9** = 1:1]; i) TMSE-OH, LiHMDS, THF, 0 °C [70%, (*S*,*R*)-**9**:(*S*,*S*)-**9** = 3:2]; j) 5 N HCl, 100 °C, 1 h; camphanoyl chloride, $NaHCO_3$, THF/H_2O; CH_2N_2, Et_2O (65%)

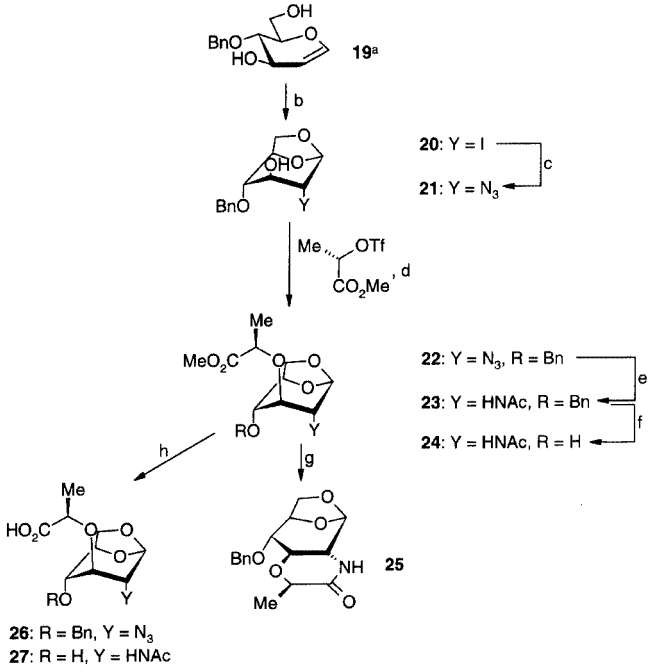
For the synthesis of the required muramic acid derivative **18** (Scheme 2), D-glucosamine was transformed into the known 2-azido derivative **11**.[26,47] Regioselective 4,6-*O*-isopropylidenation with acetone dimethyl ketal in the presence of *p*-toluenesulfonic acid (*p*-TsOH) as catalyst afforded the 3-*O*-unprotected 2-azidoglucose **12**. For the attachment of the lactic acid residue, by our previously reported procedure,[27] the triflate of methyl L-lactate **13**[48−50] was employed. In the presence of sodium hydride as base, this furnished the muramic acid derivative **14** exclusively, with the desired stereochemistry. Compound **14** is a highly versatile intermediate for carbohydrate chain extension because it can readily be transformed into a glycosyl donor and a glycosyl acceptor;[27,29−31] however, it is also available for peptide attachment. Since initial azido group reduction of **14** furnishes the undesired six-membered lactam,[46] the L-alanine residue was attached next. To this end, the methyl ester

of **14** was cleaved with lithium hydroxide in aqueous dioxane/methanol,[30] thus avoiding diastereoisomerization during the generation of **15**. Subsequent treatment with L-alanine methyl ester in the presence of EEDQ/NEt_3 as condensing agent furnished the muramyl alanine derivative **16** in high yield. Azido group reduction with hydrogen sulfide in aqueous pyridine, *N*-acetylation with acetic anhydride/pyridine (→ **17**), and methyl ester cleavage as described above provided the useful intermediate **18**. Because of the increased ring size, lactam formation was not observed in the transformation of **16** into **17**.



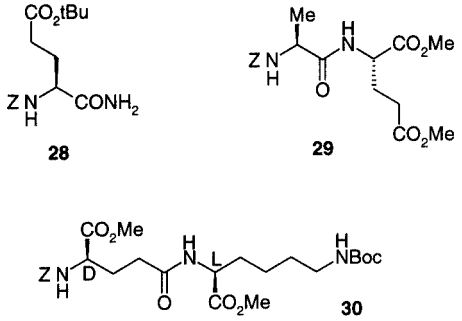
Scheme 2. Synthesis of muramic acid derivative **18**; a) refs. 26,27; b) $(MeO)_2CMe_2$, *p*-TsOH (quant.); c) NaH, CH_2Cl_2 (70−95%); d) LiOH, dioxane/MeOH (quant.); e) L-Ala-OMe·HCl, EEDQ NEt_3, CH_2Cl_2 (85%); f) H_2S, Pyr/H_2O; Ac_2O, pyr (89%); g) LiOH, dioxane/MeOH (quant.)

For the required 1,6-anhydro analogue of **15** (the known compound **26**[39]), D-glucal was transformed into the 4-*O*-benzyl derivative **19** by a literature procedure (Scheme 3).[28] Treatment of **19** with bis(tributyltin) oxide and then with iodine[51,52] afforded the 1,6-anhydro-2-deoxy-2-iodoglucose derivative **20**[53] in high yield. Treatment of **20** with tetramethylguanidinium azide (TMGA) in DMF as solvent afforded, after heating for three days, mainly the desired 2-azido-2-deoxy-D-*gluco* isomer **21**,[54−56] this reaction taking place either through formation of a *manno*-configured epoxide intermediate and regioselective ring-opening by the azide ion, or by double inversion at C-2 by traces of iodide,[52] thus furnishing a more reactive intermediate for the nucleophilic substitution with the azide ion. Transformation of **21** into **22**−**24**, **26**, and **27** followed literature procedures.[39] Surprisingly, azide reduction of **22** by the Staudinger procedure[57] afforded the *trans*-linked lactam **25**[57] in spite of the expected ring strain in the product.



Scheme 3. Synthesis of 1,6-anhydroneuramic acid derivatives **26** and **27**; a) ref. 28; b) $(Bu_3Sn)_2O$, MeCN, Δ; I_2, room temp. (89%); c) TMGA, DMF, H_2O, Δ, 3 days (79% + 15% *manno* isomer); d) NaH, CH_2Cl_2 (85−88%); e) H_2S, pyr/H_2O; Ac_2O, pyr (92%); f) Pd/C, H_2; Ac_2O; MeOH (90%); g) PPh_3, THF/H_2O; Ac_2O, pyr (75%); h) LiOH, dioxane/MeOH (quant.)

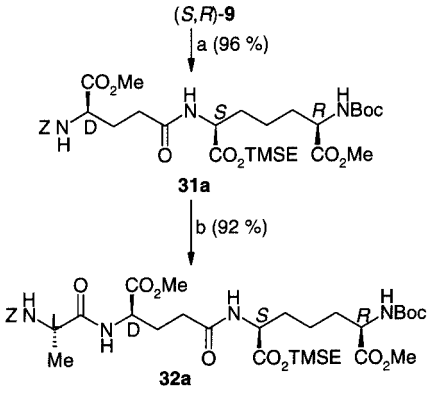
In order to arrive at the target molecules, additional amino acid and di- and tripeptide derivatives were required, standard protecting group patterns and condensing agents being employed for their synthesis. Thus, the synthesis of the D-isoglutamine derivative **28** (Scheme 4) followed the synthesis of the corresponding L isomer.[58−60] The Z-protected L-alanyl-D-glutamate derivative **29** was obtained from Z-protected L-alanine and dimethyl D-glutamate with EEDQ as condensing agent. Similarly, Z-protected methyl D-glutamate and N^{ε}-Boc-protected methyl L-lysine furnished dipeptide **30**.



Scheme 4. Building blocks **28**−**30**

Compounds (*S*,*R*)-**9** and (*S*,*S*)-**9** were employed as precursors for the synthesis of 2,6-diaminiopimelic acid containing peptides (Scheme 5). After hydrogenolytic removal

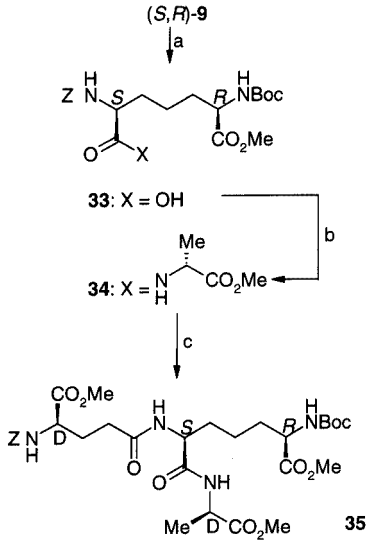
of the Z-protecting groups of (*S*,*R*)-**9** and (*S*,*S*)-**9**, treatment with Z-protected methyl D-glutamate in the presence of PyBOP/NMM as condensing agent afforded the dipeptide derivatives **31a** and **31b** in high yields. Again, hydrogenolysis of the Z group and subsequent treatment with Z-protected L-alanine and PyBOP/NMM as condensing agent furnished tripeptides **32a** and **32b**, respectively.



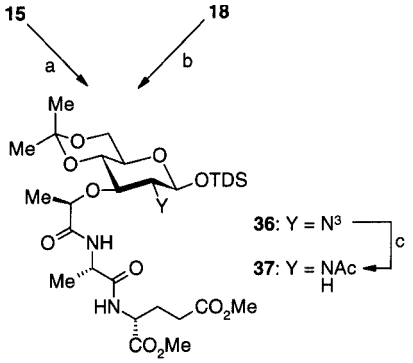
Scheme 5. Synthesis of peptides **32a** and **32b**; a) Pd/C, H_2, MeOH; Z-D-Glu-OMe, PyBOP, NMM, CH_2Cl_2; b) Pd/C, H_2, MeOH; Z-L-Ala, PyBOP, NMM, CH_2Cl_2

Selective removal of the TMSE group in (*S*,*R*)-**9** with TBAF (→ **33**) followed by condensation with D-alanine methyl ester afforded the protected dipeptide **34** (Scheme 6). Hydrogenolysis of the Z group liberated the amino group of the *S*-configured part, which afforded tripeptide **35** on condensation with Z-protected methyl glutamate.

With these amino acid and peptide compounds in hand, ligation with the muramyl residues could be carried out. Thus, hydrogenolysis of the Z group in **29** and subsequent treatment with muramic acid derivative **15**, with EEDQ/NEt_3 as condensing agent, afforded the muramyl dipeptide derivative **36** in good yield (Scheme 7). Treatment of **36** with H_2S in aqueous pyridine and then with acetic anhydride in pyridine resulted in a smooth transformation into the acetylamino derivative **37**. The same compound could be obtained directly and more efficiently from muramyl-L-alanine derivative **18** and dimethyl L-glutamate in the presence of PyBOP/NMM as condensing agent.



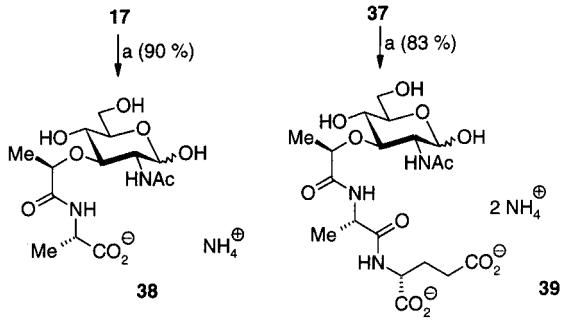
Scheme 6. Synthesis of peptide **35**; a) TBAF, THF, room temp., IR 120, H^+; b) D-Ala(OMe), PyBOP, NMM, CH_2Cl_2 (92%); c) Pd/C, H_2, MeOH; Z-D-Glu-OMe, PyBOP, NMM, CH_2Cl_2 (86%)



Scheme 7. Synthesis of muramic acid derivative **37**; a) **29**, Pd/C, H_2, MeOH; EEDQ, NEt_3 (65%); b) D-Glu(OMe)$_2$, PyBOP, NMM, CH_2Cl_2; c) H_2S, Pyr, H_2O; Ac_2O, Pyr (85%)

Complete deprotection of the muramyl peptide derivatives and purification of the desired unprotected target molecules was an important issue. To this end, the methyl ester moiety in **17** was first cleaved with lithium hydroxide in aqueous dioxane/methanol, with subsequent acid-catalyzed removal of the *O*-isopropylidene and 1-*O*-TDS groups providing the desired product **38**, which was purified by gel permeation chromatography (GPC with P_2 Biogel) and then isolated by lyophilization (Scheme 8). When the same procedure was applied to the protected muramyl peptide **37**, the unprotected muramyl dipeptide **39** was obtained as the diammonium salt. Compound **39** has physical data in accordance with material obtained by other procedures.[25,61]

For the desired muramyl di-, tri-, and tetrapeptides, particularly those containing the Dpa residue, the precursor was the muramyl L-alanine derivative **18** (Scheme 9). Thus, treatment of **18** with D-isoglutamine derivative **28**, D-isoglutaminyl-L-lysine derivative **30**, and with Dpa-containing di- and tripeptides **31a** and **35**, respectively, with PyBOP/



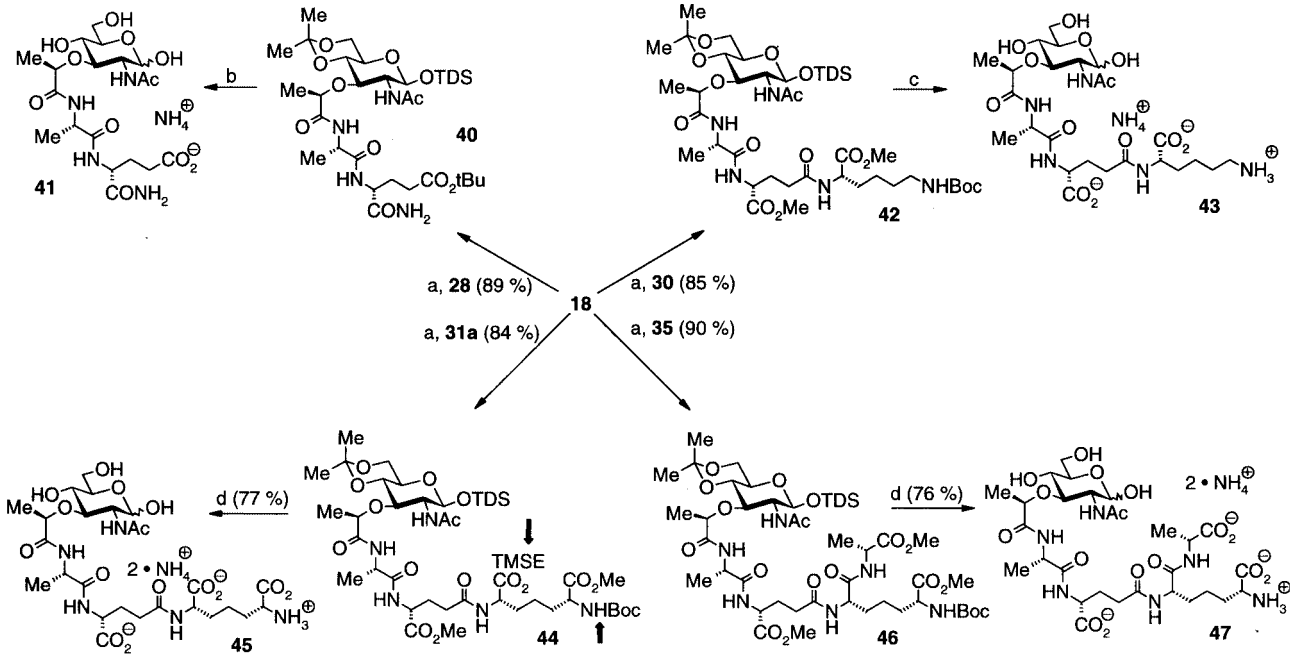
Scheme 8. Synthesis of muramic acid derivatives **38** and **39**; a) LiOH, dioxane/MeOH/H_2O, room temp., pH 9.5−10.5; TFA/H_2O/dioxane, 0 °C → room temp.; GPC (P_2-Biogel, NH_4HCO_3) lyophilization

NMM as condensing agent, afforded the protected muramyl peptides **40**, **42**, **44**, and **46** in high yields. Deprotection and purification of these compounds were important tasks. The muramyl dipeptide derivative **40** could be deprotected readily as it contained only acid-sensitive protecting groups. Hence, treatment of **40** with TFA in aqueous dioxane, with subsequent GPC and HPLC purification and lyophilization, furnished pure muramyl dipeptide (MDP) **41** as an ammonium salt that could be fully characterized from its NMR spectroscopic data (in [D_6]DMSO/TFA); these were in good agreement with those reported for the free acid of MDP.[25,61−66] The methyl ester group containing compounds **42**, **44**, and **46** first required ester cleavage; removal of the acid-sensitive protecting groups was then carried out to afford the target molecules **43**, **45**, and **47**, respectively, after purification.

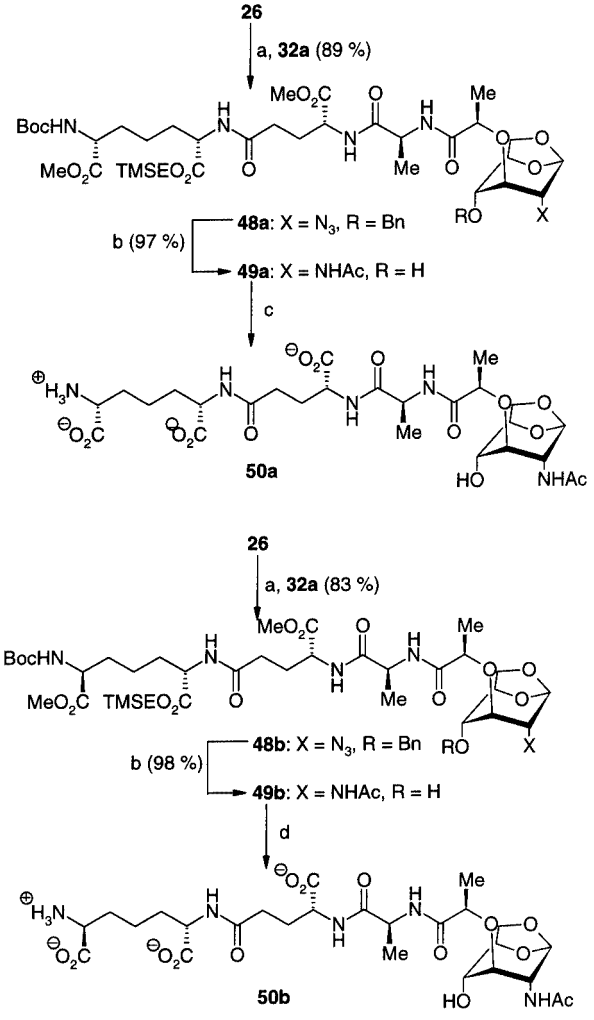
For the completion of the synthesis of the desired 1,6-anhydromuramyl tripeptides **50a** and **50b** (Scheme 10), similar procedures were applied. Hydrogenolytic removal of the Z groups in **32a** and **32b** and subsequent condensation with the 1,6-anhydromuramic acid derivative **26** in the presence of PyBOP/NMM as condensing agent afforded compounds **48a** and **48b**, respectively. Hydrogenation of the azido group and *N*-acetylation of the generated amino group then afforded acetylamino derivatives **49a** and **49b**. Because the reducing end of the sugar moiety was blocked, the sequence of the deprotection steps was not as critical as for the previous compounds. The acid-sensitive protecting groups were hence removed first, and the methyl esters were then cleaved with lithium hydroxide in aqueous methanol. For purification, **50a** was first subjected to ion-exchange chromatography on RP-18; lyophilization then afforded pure **50a**. For **50b** a second ion-exchange chromatography procedure was carried out, thus providing pure material. All compounds had ^1H and ^{13}C NMR spectroscopic data and mass spectra data in accordance with their assigned structures.

Conclusion

Various 2,6-diaminiopimelic acid containing (Dpa-containing) muramyl- and 1,6-anhydromuramyl di-, tri-, and tetrapeptides were synthesized in good yields. The immunostimulatory properties of these compounds and their comparison with those of the famous muramyl dipeptide will be reported in due course.



Scheme 9. Synthesis of muramyl peptides **41**, **43**, **45**, and **47**; a) Pd/C, H_2, MeOH; **28**, **30**, **31a**, or **35**, Py BOP, NMM, CH_2Cl_2; b) TFA/H_2O/dioxane, 0 °C → room temp.; GPC (B-2 Biogel, NH_4HCO_3); HPLC (H_2O, MeCN, TFA); lyophilization (68%); c) LiOH, dioxane/H_2O/MeOH, pH ≈ 10, room temp.; TFA/H_2O/dioxane, 0 °C → room temp.; GPC (P-2 Biogel NH_4HCO_3); HPLC (H_2O, MeCN, TFA); lyophilization (64%); d) LiOH, dioxane/H_2O/MeOH, pH ≈ 10, room temp.; TFA/H_2O/dioxane, 0 °C → room temp.; GPC (P-2 Biogel, NH_4HCO_3); lyophilization



Scheme 10. Synthesis of 1,6-anhydromuramylpeptides **50a** and **50b**; a) Pd/C, H_2, MeOH; Py BOP, NMM, DMF; b) Pd/C, H_2, MeOH; Ac_2O; c) TFA, CH_2Cl_2, room temp.; LiOH, H_2O/MeOH, pH ≈ 10, room temp.; Dowex 50 W; RP-18 (MeCN/H_2O); lyophilization (86%); d) TFA, CH_2Cl_2, room temp.; LiOH, H_2O/MeOH, pH ≈ 10, room temp.; Dowex 50 W; RP-18 (MeCN/H_2O); Dowex 50 W; lyophilization (77%)

Experimental Section

General Methods: Unless specified otherwise, all reactions requiring anhydrous conditions were performed in flame-dried glassware under an atmosphere of anhydrous nitrogen with starting reagents that had been dried in vacuo before use. The appropriate solvents were freshly distilled from sodium/benzophenone (THF) or calcium hydride (CH_2Cl_2) immediately prior to use. Other chemicals and reagents were either purchased puriss. p.A. from commercial suppliers or purified by standard techniques. For analytical thin layer chromatography (TLC), plastic silica gel plates (Merck 60 F254) were used, and compounds were viewed by irradiation with UV light and/or by immersion in solutions of ammonium molybdate (20 g) and $Ce(SO_4)_2$ (400 mg) in 10% H_2SO_4 (400 mL) or a 15% H_2SO_4 solution or a 1% ninhydrin solution in EtOH, each followed by heating. Preparative flash chromatography was performed at a pressure of 1.3−1.4 bar on J. T. Baker 60 silica gel (0.040−0.063 mm, 230−400 mesh). Medium-pressure liquid chromatography was performed at a pressure of 5−12 bar on Merck LiChroprep Si 60 silica gel (0.015−0.025 mm, column size: 28 × 2.5 cm, flow rate: 10 mL/min; 40 × 4.5 cm, flow rate: 20 mL/min, detection by Knauer differential refractometer). Analytical HPLC was performed on a Knauer Eurospher-100 column (5 μm Si, 250 × 4.0 mm ID) on a Merck/Hitachi system (L-6200 pump, D-6000 HPLC manager; detection with an ACS Ltd. 950:14 mass detector, air flow: 9.0 l/min, air temperature: 110 °C, time const: 0 sec). Preparative HPLC was performed with a sampler (CSI) and gradient controller (CIM) from Autochrom, a Shimadzu pump (LC-8A), a Knauer UV detector, and a Knauer Eurospher-100 C18 column (7 μm, 250 × 16 mm). Gel permeation chromatography was performed on a Pharmacia XK16 column (50 × 1.6 cm) filled with Biorad P2 Biogel (eluent: 30 mM aqueous NH_4HCO_3, flow rate: 1 mL/min, detection with a Knauer differential refractometer). Melting points are uncorrected. Optical rotations were determined with a Büchi Polar-Monitor (1 dm cell, temperature 20 °C, λ = 589 nm). Unless specified otherwise, ^1H NMR and ^{13}C NMR spectra were recorded at room temperature on either Bruker AC 250 Cryospec or Bruker DRX 600 machines. Chemical shifts are given in δ relative to tetramethylsilane as an internal standard, the coupling constants *J* are given in Hz. Assignment of peaks was based upon DQF-Cosy, HMQC, HMBC, and ROESY experiments. MALDI-TOF mass spectra were recorded on a Kratos Analytical Kompact MALDI 1 spectrometer with a DHB matrix. FAB mass spectra were recorded on a modified Finnigan MAT 312/AMD 5000. EI mass spectra were recorded on a Finnigan MAT 312 spectrometer.

General Procedure for Z-Cleavage (Procedure A): Pearlman's catalyst[67] (10%) or Pd/C (10%) was added to a vigorously stirred solution (0.02−0.03 M) of the Z-protected peptide in MeOH, maintained under a hydrogen atmosphere. Cleavage of the Z group was normally accomplished within 30 min (as judged by TLC), after which the suspension was filtered through celite, washed twice with MeOH, and concentrated. The residue was coevaporated several times with dry toluene, dried in vacuo for 2 h, and employed in subsequent peptide couplings without further purification.

General Procedure for Peptide Couplings in CH_2Cl_2 (Procedure B): The free carboxylic acids and free amines were dried thoroughly as described in Procedure A, provided that they were not crystalline or lyophilized. The free acid (1−1.2 equiv.), free amine (1−1.2 equiv.), and PyBOP[68] (1.1−1.3 equiv.) were dissolved in freshly distilled, dry CH_2Cl_2 to give solutions of approximately 0.2 M concentration (≈ 0.07 M per component). The pH was adjusted to ≈ 9−9.5 with *N*-methylmorpholine (NMM) and maintained in this range during the reaction. The reaction mixture was stirred under nitrogen at room temperature for 1−2 h. After completion of the reaction, the solution was diluted with CH_2Cl_2 and extracted several times with small portions of saturated NH_4Cl solution. The combined organic layers were dried over $MgSO_4$, filtered, and concentrated in vacuo. The crude products were purified by flash chromatography on silica gel.

General Procedure for Peptide Couplings in DMF (Procedure C): The reaction was performed according to Procedure B, except for the use of dry DMF (Fluka) instead of CH_2Cl_2. When the reaction was complete (as judged by TLC), the residue was coevaporated several times with toluene in order to remove traces of DMF and then worked up as described above.

General Procedure for Alkaline Ester Saponification (Procedure D): A solution of the starting ester (0.03−0.06 M) in a mixture of dioxane/MeOH (1:1 v/v) was adjusted exactly to pH 10.0 (pH meter) by addition of an aqueous LiOH solution (1 M) at room temperature. In the event of the solution becoming cloudy, additional

MeOH was added until the solution became clear. The pH should not drop below 9.5, nor exceed 10.0. Thus, during the reaction, decreasing pH values were compensated for by addition of base. Completion of the reaction (as judged by TLC or NMR spectroscopy) was generally accomplished within 2−3 h. The alkaline solution was neutralized with acidic ion exchange resin (Amberlite IR 120 H^+) and filtered, and the solvents were evaporated to dryness in vacuo.

General Procedure for the Hydrolysis of Acid-labile Protecting Groups (Procedure E): An ice-cooled mixture of TFA/dioxane/H_2O (4:3:3 v/v/v) was added slowly to a stirred solution of the starting material (0.003−0.015 M), and the mixture was allowed to warm to room temperature. The reaction mixture was stirred for 2 h and then concentrated under vacuum at low temperature (≤ 25 °C) to a final volume of 1−1.5 mL. The residue was coevaporated several times with H_2O and toluene to remove all traces of acid, evaporated to dryness, dissolved in H_2O, and lyophilized. The crude products were purified by suitable chromatographic methods.

(*S*)-3-(3-Benzyloxycarbonyl-5-oxo-1,3-oxazolidin-4-yl)propionaldehyde (3). (a) From 2: Under anhydrous conditions, a borane/dimethyl sulfide complex in THF (2 M, 50 mL, 100 mmol, Fluka) was added slowly at 0 °C over 15−20 min to a solution of compound **2** (21.63 g, 73.8 mmol) in THF (150 mL). The resulting mixture was stirred at 0 °C for 15 min and then allowed to warm to room temperature and stirred until no starting material was detectable by TLC. The solvent was then evaporated in vacuo (30 °C). The residue was dissolved in dry CH_2Cl_2 (500 mL) and the flask was put in a water bath (20 °C). Dess−Martin periodinane[43] (49 g, 117 mmol) was added in small portions to keep the temperature between 20−40 °C. After complete oxidation of the alcohol (TLC, SiO_2, R_f = 0.32, toluene/acetone = 2:1), the reaction mixture was diluted with Et_2O (500 mL), treated with 25% NaS_2O_3 solution (250 mL) and 5% $NaHCO_3$ (50 mL), and stirred at 0 °C for 1 h. The mixture was allowed to warm to room temperature, and the organic layer was separated and washed twice with H_2O (200 mL) and saturated NaCl solution (200 mL). The combined organic layers were dried over $MgSO_4$, filtered, and concentrated in vacuo. The residue was purified by flash chromatography [dry (!) silica gel, petroleum ether/EtOAc = 3:1] to afford the aldehyde **3** (10.8 g, 39.0 mmol, 53%) as a yellow syrup. TLC (SiO_2): R_f = 0.61 (toluene/acetone = 2:1).

(b) From 4: Aldehyde **3** was prepared according to the procedure reported by Gelb et al.[44] The spectroscopic data were identical to those reported.[44]

Methyl (*Z*,*S*)-5-(3-Benzyloxycarbonyl-5-oxo-1,3-oxazolidin-4-yl)-2-[(*tert*-butyloxycarbonyl)amino]-2-pentenoate [(*Z*)-6] and Methyl (*E*,*S*)-5-(3-Benzyloxycarbonyl-5-oxo-1,3-oxazolidin-4-yl)-2-[(*tert*-butyloxycarbonyl)amino]-2-pentenoate [(*E*)-6]: Solid KHMDS (5.0 g, 25 mmol, Aldrich) was placed in a heat-dried flask under a nitrogen atmosphere. The flask was cooled to −78 °C and dry THF (150 mL) was then used to dissolve the base. A solution of **5**[45] (8.3 g, 28 mmol) in dry THF (150 mL) was added dropwise. The resulting yellow mixture was warmed to −55 °C, stirred for 15 min, then cooled again to −78 °C. Aldehyde **3** (7.0 g, 25 mmol) in dry THF (100 mL) was added dropwise to give an orange colored solution. After complete addition, the reaction mixture was brought to −30 °C. At this point the reaction was quenched with saturated NH_4Cl solution (≈ 200 mL), resulting in a pH of ≈ 9. At 5−10 °C, the reaction mixture was extracted with Et_2O (4 × 170 mL), and the combined organic layers were dried over $MgSO_4$, filtered, and concentrated in vacuo. Purification of the residue by flash chromatography (SiO_2, petroleum ether/EtOAc = 4:1) afforded (*Z*)-**6** (8.58 g, 19.1 mmol, 76%) and (*E*)-**6** (1.32 g, 2.9 mmol, 12%) in a 6.5:1 ratio as colorless, syrupy compounds.

(*Z*)-6: TLC (SiO_2): R_f = 0.75 (petroleum ether/EtOAc = 1:1). $[\alpha]_D$ = +63.9 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, $CDCl_3$, 320 K): δ = 1.39 [s, 9 H, $C(CH_3)_3$], 2.01, 2.13 (2m, 2 H, 5-CH_2), 2.22−2.28 (m, 2 H, 4-CH_2), 3.70 (s, 3 H, OCH_3), 4.26 [t, ^3J = 4.8 Hz, 1 H, NC*H*RC(O)], 5.09−5.16 (m, 3 H, CH_2Ph, NC*H*HOC(O)], 5.44 [br. s, 1 H, NCH*H*OC(O)], 6.1 (br. s, 1 H, Boc-NH), 6.36 (m, 1 H, 3-H), 7.28−7.32 (m, 5 H, Ph) ppm. ^{13}C NMR (150.8 MHz, $CDCl_3$): δ = 23.7,(1C, 4-C), 28.2 [3C, C(CH_3)$_3$], 29.2 (1C, 5-C), 52.3 (1C, OCH_3), 54.5 [1C, N*C*HRC(O)], 68.1 (1C, *C*H_2Ph), 77.9 [1C, N*C*H_2OC(O)], 80.7 [1C, *C*(CH_3)$_3$], 128.3, 128.6, 128.7 (5C, Ph), 132.9 (1C, 3-C), 135.4 (1C, Ph), 152.9, 153.1 [2C, 2 OC(O)N], 165.0 (1C, *C*O_2CH_3), 172.0 [1C, NCH_2O*C*(O)] ppm. EI MS (160 °C): *m*/*z* = 448 $[M]^+$; calcd. 448.5 for $C_{22}H_{28}N_2O_8$.

(*E*)-6: TLC (SiO_2): R_f = 0.83 (petroleum ether/EtOA*c* = 1:1). $[\alpha]_D$ = +52.9 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, $CDCl_3$, 320 K): δ = 1.39 [s, 9 H, $C(CH_3)_3$], 1.99, 2.11 (2m, 2 H, 5-CH_2), 2.52−2.56 (m, 2 H, 4-CH_2), 3.71 (s, 3 H, OCH_3), 4.28 (m, 1 H, NC*H*RC(O)], 5.11−5.15 (m, 3 H, CH_2Ph, NC*H*HOC(O)], 5.44 (br. s, 1 H, NCH*H*OC(O)], 6.50 (br. s, 1 H, Boc-NH), 6.62 (br. s, 1 H, 3-H), 7.27−7.31 (m, 5 H, Ph) ppm. ^{13}C NMR (150.8 MHz, $CDCl_3$): δ = 23.3, (1C, 4-C), 28.3 (3C, C(CH_3)$_3$], 30.6 (1C, 5-C), 52.2 (1C, OCH_3), 54.6 (1C, N*C*HRC(O)], 68.0 (1C, *C*H_2Ph), 77.9 (1C, N*C*H_2OC(O)], 80.5 (1C, *C*(CH_3)$_3$], 126.2 (1C, 3-C), 128.3, 128.6, 128.7, 135.5 (6C, Ph), 153.0 (2C, 2 OC(O)N), 164.4 (1C, *C*O_2CH_3), 171.9 (1C, NCH_2O*C*(O)] ppm. MALDI MS (positive mode, DHB, THF): *m*/*z* = 471 $[M + Na]^+$; calcd. 448.5 for $C_{22}H_{28}N_2O_8$.

1-Methyl 7-[2-(Trimethylsilyl)ethyl] (*Z*,*S*)-6-[(Benzyloxycarbonyl)-amino]-2-[(*tert*-butyloxycarbonyl)amino]-2-heptenedioate [(*Z*)-7]: Under anhydrous conditions, 610 μL (122 μmol) of a freshly prepared 0.2 M solution of LiHMDS (167 mg, 1 mmol, Aldrich, in 5 mL THF) was added dropwise by syringe at 0 °C to oxazolidine (*Z*)-**6** (210 mg, 0.48 mmol) and 2-(trimethylsilyl)ethanol (85 mg, 0.7 mmol) in THF (10 mL). When the reaction was complete (after 15−30 min as judged by TLC), the pH was adjusted to ≈ 9 by addition of saturated NH_4Cl. The organic layer was extracted with Et_2O (3 × 20 mL), dried ($MgSO_4$), and concentrated in vacuo. Purification of the residue by flash chromatography (SiO_2, petroleum ether/EtOAc = 4:1) afforded (*Z*)-**7** (167 mg, 0.31 mmol, 65%) as a light yellow oil. TLC (SiO_2): R_f = 0.84 (petroleum ether/EtOAc = 1:1). $[\alpha]_D$ = −2.4 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO, 298 K): δ = 0.01 [s, 9 H, Si(CH_3)$_3$], 0.92 [t, ^3J = 8.5 Hz, 2 H, OCH_2CH_2Si(CH_3)$_3$], 1.36 [s, 9 H, C(CH_3)$_3$], 1.65−1.69, 1.76−1.79 (2m, 2 H, 5-CH_2), 2.14−2.16 (m, 2 H, 4-CH_2), 3.64 (s, 3 H, OCH_3), 3.95−3.98 (m, 1 H, 6-H), 4.11 [t, ^3J = 8.5 Hz, 2 H, OCH_2CH$_2$Si(CH_3)$_3$], 4.99−5.05 (m, 2 H, CH_2Ph), 6.2 (br. s, 1 H, 3-H), 7.31−7.37 (m, 5 H, Ph), 7.69 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Z-NH), 8.3 (br. s, 1 H, Boc-NH) ppm. ^{1}H NMR (600 MHz, 374 K): δ = 0.03 [s, 9 H, Si(CH_3)$_3$], 0.94 [t, ^3J = 8.1 Hz, 2 H, OCH$_2$CH_2Si(CH_3)$_3$], 1.39 [s, 9 H, C(CH_3)$_3$], 1.74−1.76, 1.82−1.84 (2m, 2 H, 5-CH_2), 2.19−2.22 (m, 2 H, 4-CH_2), 3.66 (s, 3 H, OCH_3), 4.02 (m, 1 H, 6-H), 4.14 [t, ^3J = 8.1 Hz, 2 H, OCH_2CH$_2$Si(CH_3)$_3$], 5.04 (s, 2 H, CH_2Ph), 6.24 (t, $^3J_{\gamma,\delta}$ = 7.3 Hz, 1 H, 3-H), 7.30−7.35 (m, 6 H, Ph, NH), 7.88 (s, 1 H, NH) ppm. $C_{26}H_{40}N_2O_8Si$ (536.7): calcd. C 58.19, H 7.51, N 5.22; found C 58.11, H 7.11, N 5.12.

Methyl (2*R*,4′*S*)-5-(3-Benzyloxycarbonyl-5-oxo-1,3-oxazolidin-4-yl)-2-[(*tert*-butyloxycarbonyl)amino]-pentanoate [(*S*,*R*)-8] and Methyl (2*S*,4′*S*)-5-(3-Benzyloxycarbonyl-5-oxo-1,3-oxazolidin-4-yl)-2-[(*tert*-butyloxycarbonyl)amino]-pentanoate [(*S*,*S*)-8]: Wilkinson's catalyst (2.0 g, 2 mmol) was added to a solution of the diastereo-

meric mixture of (*Z*)-**6** and (*E*)-**6** (7.5 g, 16.8 mmol) in oxygen-free MeOH (300 mL). The reaction mixture was hydrogenated under normal pressure, during which time the initially dark red solution changed to a light orange color. The reaction was monitored by NMR spectroscopy, and when it was complete (24−72 h) the solution was filtered through Celite, washed twice with MeOH, and concentrated in vacuo. The residue was purified by flash chromatography (SiO_2, petroleum ether/EtOAc = 3:1) to give an inseparable mixture of the *R* and *S* isomers (*S*,*R*)-**8** and (*S*,*S*)-**8** as a dark brown syrup (6.8 g, 15.1 mmol, 90%) in a ratio of 3:2, favoring the *R* isomer as determined by NMR spectroscopy. TLC (SiO_2): R_f = 0.83 (petroleum ether/EtOAc = 1:1). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.30−2.10 (m, 6 H, 3-CH_2, 4-CH_2, 5-CH_2), 1.41 [s, 9 H, $C(CH_3)_3$], 3.69, 3.70 (2s, 3 H, OCH_3), 4.25−4.29 [m, 2 H, 2-H, NCHRC(O)], 4.95−5.20 [m, 3 H, CH_2Ph, NCHHOC(O), Boc-NH], 5.50 [br. s, 1 H, NCHHOC(O)], 7.35−7.36 (m, 5 H, Ph) ppm. ^{13}C NMR (62.9 MHz, $CDCl_3$): δ = 20.2, 20.4 (1C, 4-C), 28.2 (3C, $C(CH_3)_3$], 30.1, 32.3 (2C, 3-C, 5-C), 52.2 (1C, OCH_3), 53.0 (1C, 2-C), 54.6 [1C, NCHRC(O)], 68.0 (1C, CH_2Ph), 77.9 [1C, $NCH_2OC(O)$], 79.9 [1C, $C(CH_3)_3$], 128.0, 128.3, 128.5, 128.6, 128.7, 135.3 (6C, Ph), 152.9, 155.3 [2C, 2 OC(O)N], 172.0, 172.9 [2C, CO_2CH_3, $NCH_2OC(O)$] ppm. FAB MS (positive mode, glycerol, THF): *m*/*z* = 473 $[M + Na]^+$; calcd. 450.5 for $C_{22}H_{30}N_2O_8Si$.

7-Methyl 1-[2-(Trimethylsilyl)ethyl] (2*S*,6*R*)-*N*$^{\alpha}$-Benzyloxycarbonyl-*N*$^{\varepsilon}$-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate [(*S*,*R*)-9] and 7-Methyl 1-[2-(Trimethylsilyl)ethyl] (2*S*,6*S*)-*N*$^{\alpha}$-Benzyloxycarbonyl-*N*$^{\varepsilon}$-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate [(*S*,*S*)-9]. (a) *From* (*Z*)-7: Pearlman's catalyst (200 mg) was used (according to Procedure A) for the hydrogenation of compound **7** (4.3 g, 8 mmol) in MeOH (100 mL). The product mixture (TLC, SiO_2, R_f = 0.46−0.51, $CHCl_3$/MeOH = 9:1) was filtered through celite, washed with MeOH (2 × 50 mL), evaporated under vacuum, and dissolved in THF (15 mL). Aqueous $NaHCO_3$ (1 M, 15 mL) and benzyl chloroformate (1.6 g, 10 mmol) were added to the vigorously stirred solution. The reaction mixture was extracted after 1 h with Et_2O (4 × 50 mL), the combined organic layers were dried ($MgSO_4$), and the solvents were evaporated to dryness. Purification of the crude product by flash chromatography (SiO_2, petroleum ether/EtOAc = 4:1) gave a mixture of diastereomers (*R*,*S*)-**9** and (*S*,*S*)-**9** in a 1:1 ratio and as a colorless oil (3.0 g, 5.6 mmol, 70%).

(b) *From* (*S*,*R*)/(*S*,*S*)-8: This reaction was performed as described for (*Z*)-**7**. 2-(Trimethylsilyl)ethanol (2.4 mL, 17 mmol) and LiHMDS (0.2 M, 22 mL, 4.4 mmol) were added at 0 °C to a solution of the oxazolidinones (*S*,*R*)/(*S*,*S*)-**8** (5 g, 11 mmol) in THF (60 mL). Purification of the products by flash chromatography (SiO_2, petroleum ether/EtOAc = 3:2) afforded a mixture of diastereomers (*S*,*R*)-**9** and (*S*,*S*)-**9** in a 3:2 ratio and as a colorless oil (4.2 g, 7.8 mmol, 70%).

(c) *Separation of Diastereomers* (*S*,*R*)-9 and (*S*,*S*)-9: The diastereomeric mixture (450 mg) in 4.5 mL eluent (toluene/EtOAc = 5:1) was subjected to MPLC (40 × 4.5 cm). The products generally eluted at t_R = 45.9 min [(*S*,*S*)-**9**] and t_R = 50.1 min [(*S*,*R*)-**9**]. Pure fractions were collected, while mixed fractions were reinjected for final separation.

(d) *HPLC analysis of MPLC separation*: A sample (0.1 mL) of each MPLC fraction was dried in vacuo and then dissolved in toluene (40 μL). From each solution, 20 μL were subjected to HPLC analysis (toluene/EtOAc = 9:1, 1 mL/min). Compounds (*S*,*R*)-**9** (t_R = 12.5 min) and (*S*,*S*)-**9** (t_R = 10.8 min) were fully separated.

(*S*,*R*)-9: TLC (HPTLC): R_f = 0.48 (toluene/EtOAc = 3:1). $[\alpha]_D$ = −4.9 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, $[D_6]$DMSO): δ = 0.02 [s, 9 H, $Si(CH_3)_3$], 0.91 [t, ^3J = 8.3 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 1.32 (m, 2 H, 4-CH_2), 1.36 [s, 9 H, $C(CH_3)_3$], 1.53−1.56, 1.59−1.64 (2m, 4 H, 3-CH_2, 5-CH_2), 3.59 (s, 3 H, OCH_3), 3.90−3.94 (m, 2 H, 2-H, 6-H), 4.11 [t, ^3J = 8.3 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 5.02 (m, 2 H, CH_2Ph), 7.18 (d, $^3J_{6,NH}$ = 7.6 Hz, 1 H, Boc-NH), 7.30−7.35 (m, 5 H, Ph), 7.64 (d, $^3J_{2,NH}$ = 7.6 Hz, 1 H, Z-NH) ppm. ^{13}C NMR (150.8 MHz, $[D_6]$DMSO): δ = −1.5 [3C, $Si(CH_3)_3$], 16.8 [1C, $OCH_2CH_2Si(CH_3)_3$], 21.9 (1C, 4-C), 28.1 [3C, $CCH_3)_3$], 30.2 (2C, 3-C, 5-C), 51.6 (1C, OCH_3), 53.2, 53.8 (2C, 2-C, 6-C), 62.5 [1C, $OCH_2CH_2Si(CH_3)_3$], 65.4 (1C, CH_2Ph), 78.1 [1C, $C(CH_3)_3$], 127.7, 127.8, 128.3, 136.9 (6C, Ph), 155.5, 156.0 [2C, 2 OC(O)NH], 172.2, 172.9 [2C, CO_2CH_3, $CO_2(CH_2)_2Si(CH_3)_3$] ppm. $C_{26}H_{42}N_2O_8Si$ (538.7): calcd. C 57.97, H 7.86, N 5.20; found C 57.88, H 7.76, N 5.03.

(*S*,*S*)-9: TLC (HPTLC): R_f = 0.51 (toluene/EtOAc = 3:1). $[\alpha]_D$ = −16.5 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, $[D_6]$DMSO): δ = 0.02 [s, 9 H, $Si(CH_3)_3$], 0.92 [t, ^3J = 8.4 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 1.31−1.34 (m, 2 H, 4-CH_2), 1.36 [s, 9 H, $C(CH_3)_3$], 1.56−1.63 (m, 4 H, 3-CH_2, 5-CH_2), 3.59 (s, 3 H, OCH_3), 3.89−3.94 (m, 2 H, 2-H, 6-H), 4.11 [t, ^3J = 8.3 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 4.99−5.04 (m, 2 H, CH_2Ph), 7.17 (d, $^3J_{6,NH}$ = 7.4 Hz, 1 H, Boc-NH), 7.30−7.37 (m, 5 H, Ph), 7.63 (d, $^3J_{2,NH}$ = 7.4 Hz, 1 H, Z-NH) ppm. ^{13}C NMR (150.8 MHz, $[D_6]$DMSO): δ = −1.5 [3C, $Si(CH_3)_3$], 16.7 [1C, $OCH_2CH_2Si(CH_3)_3$], 22.1 (1C, 4-C), 27.8, 28.1 [3C, $CCH_3)_3$], 30.2, 30.2 (2C, 3-C, 5-C), 51.6 (1C, OCH_3), 53.3, 53.8 (2C, 2-C, 6-C), 62.5 [1C, $OCH_2CH_2Si(CH_3)_3$], 65.4 (1C, CH_2Ph), 78.1 [1C, $C(CH_3)_3$], 127.2, 127.7, 127.8, 128.3, 136.9 (6C, Ph), 155.5, 156.0 [2C, 2 OC(O)NH], 172.3, 173.0 [2C, CO_2CH_3, $CO_2(CH_2)_2Si(CH_3)_3$] ppm. $C_{26}H_{42}N_2O_8Si$ (538.7): calcd. C 57.97, H 7.86, N 5.20; found C 58.09, H 7.62, N 5.12.

Thexyldimethylsilyl 2-Azido-2-deoxy-4,6-*O*-isopropylidene-β-D-glucopyranoside (12): Dry *p*-toluenesulfonic acid (60 mg, 0.33 mmol) was added to a solution of **11**[47] (10.0 g, 28.82 mmol) in 2,2-dimethoxypropane (40 mL), and the mixture was then stirred overnight at room temperature. After complete consumption of the starting material (as judged by TLC), the solution was neutralized with triethylamine and concentrated in vacuo. Purification of the residue by flash chromatography (SiO_2, toluene/acetone = 20:1) afforded **12** (10.9 g, 28.12 mmol, 98%) as a colorless syrup. TLC (SiO_2): R_f = 0.41 (toluene/acetone = 10:1). $[\alpha]_D$ = −18.2 (*c* = 1, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.15, 0.17 [2s, 6 H, $Si(CH_3)_2$], 0.85 (s, 6 H, 2 CH_3), 0.87 [d, ^3J = 6.3 Hz, 6 H, $CH(CH_3)_2$], 1.41, 1.49 [2s, 6 H, $C(CH_3)_2$], 1.64 [quint, ^3J = 6.9 Hz, 1 H, $CH(CH_3)_2$], 2.78 (br. s, 1 H, OH), 3.20 (m, 1 H, 5-H), 3.24 (dd, $^3J_{2,3} \approx {}^3J_{1,2}$ = 7.6 Hz, 1 H, 2-H), 3.45 (t, $^3J_{3,4}$ = 9.3 Hz, 1 H, 3-H), 3.56 (t, $^3J_{4,5}$ = 9.1 Hz, 1 H, 4-H), 3.76 (t, $^2J_{6,6'}$ = 10.7 Hz, 1 H, 6-H), 3.85 (dd, $^3J_{5,6'}$ = 5.7, $^2J_{6,6'}$ = 10.8 Hz, 1 H, 6′-H), 4.54 (d, $^3J_{1,2}$ = 7.6 Hz, 1 H, 1-H) ppm. $C_{17}H_{33}N_3O_5Si$ (387.6): calcd. C 52.69, H 8.58, N 10.84; found C 52.66, H 8.71, N 10.38.

Thexyldimethylsilyl 2-Azido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-[(1*R*)-1-(methoxycarbonyl)ethyl]-β-D-glucopyranoside (14): Methyl (*S*)-2-(trifluoromethanesulfonyloxy)propionate (**13**,[48−50] 0.79 g, 3.3 mmol) was used for the alkylation of **12** (1 g, 2.6 mmol), as published previously.[27] Purification of the crude product by flash chromatography (SiO_2, petroleum ether/EtOAc = 15:1) afforded **14** in variable yields (0.85−1.18 g, 1.8−2.5 mmol, 70−95%) as a light yellow syrup. TLC (SiO_2): R_f = 0.68 (toluene/acetone = 10:1). $[\alpha]_D$ = −35.5 (*c* = 1, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.12, 0.14 [2s, 6 H, $Si(CH_3)_2$], 0.84 (s, 6 H, 2 CH_3), 0.86 [d, ^3J = 6.7 Hz, 6 H, $CH(CH_3)_2$], 1.36 [s, 3 H, $C(CH_3)_2$], 1.37 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH_3), 1.46 [s, 3 H, $C(CH_3)_2$], 1.62 [m, ^3J = 6.7 Hz, 1 H, $CH(CH_3)_2$], 3.15 (m, 1 H, 5-H), 3.25 (dd, $^3J_{1,2}$ = 7.6,

$^3J_{2,3}$ = 9.5 Hz, 1 H, 2-H), 3.37 (dd, $^3J_{2,3} \approx {}^3J_{3,4}$ = 9.4 Hz, 1 H, 3-H), 3.64 (dd, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.3 Hz, 1 H, 4-H), 3.73 (t, $^2J_{6,6'}$ = 10.7 Hz, 1 H, 6-H), 3.75 (s, 3 H, OCH_3), 3.83 (dd, $^3J_{5,6'}$ = 5.7, $^2J_{6,6'}$ = 10.7 Hz, 1 H, 6′-H), 4.37 (q, $^3J_{\alpha,\beta}$ = 6.8 Hz, 1 H, Lac-α-H), 4.45 (d, $^3J_{1,2}$ = 7.6 Hz, 1 H, 1-H) ppm. $C_{21}H_{39}N_3O_7Si$ (473.6): calcd. C 53.25, H 8.30, N 8.87; found C 53.35, H 8.26, N 8.62.

Thexyldimethylsilyl 2-Azido-3-*O*-[(1*R*)-1-carboxyethyl]-2-deoxy-4,6-*O*-isopropylidene-β-D-glucopyranoside (15): Saponification of methyl ester **14** (200 mg, 0.42 mmol) according to Procedure D afforded the free acid **15** (193 mg, 0.42 mmol, quant.) as a glassy, colorless solid. The solid was coevaporated several times with toluene, dried in vacuo, and then used directly in the next step.

TLC (SiO_2): R_f = 0.83 ($CHCl_3$/MeOH = 3:1). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.15, 0.18 [2s, 6 H, $Si(CH_3)_2$], 0.85 (s, 6 H, 2 CH_3), 0.86 [d, ^3J = 6.7 Hz, 6 H, $CH(CH_3)_2$], 1.37 [s, 3 H, $C(CH_3)_2$], 1.44 (d, $^3J_{\alpha,\beta}$ = 7.0 Hz, 3 H, Lac-β-CH_3), 1.49 [s, 3 H, $C(CH_3)_2$], 1.61 [quint, ^3J = 6.8 Hz, 1 H, $CH(CH_3)_2$], 3.16−3.24 (m, 2 H, 3-H, 5-H), 3.34 (dd, $^3J_{1,2}$ = 7.4, $^3J_{2,3}$ = 10.0 Hz, 1 H, 2-H), 3.66 (t, $^3J_{3,4}$ = 9.3 Hz, 1 H, 4-H), 3.75 (t, $^2J_{6,6'}$ = 10.1 Hz, 1 H, 6-H), 3.86 (dd, $^3J_{5,6'}$ = 5.6, $^2J_{6,6'}$ = 10.9 Hz, 1 H, 6′-H), 4.41 (q, $^3J_{\alpha,\beta}$ = 7.0 Hz, 1 H, Lac-α-H), 4.64 (d, $^3J_{1,2}$ = 7.4 Hz, 1 H, 1-H); calcd. 459.6 for $C_{20}H_{37}N_3O_7Si$.

Thexyldimethylsilyl 2-Azido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-[(2*R*)-propionyl-(L-alanine methyl ester)-2-yl]-β-D-glucopyranoside (16): EEDQ (4.64 g, 18.8 mmol) and triethylamine (1.26 g, 12.5 mmol) were added to a stirred solution of the acid **15** (5.76 g, 12.5 mmol) and L-alanine methyl ester hydrochloride (1.74 g, 12.5 mmol) in dry CH_2Cl_2 (150 mL). After 18 h, complete consumption of the acid was observed by TLC. The solution was diluted with CH_2Cl_2 (100 mL) and washed with HCl (2 M, 3 × 75 mL), saturated $NaHCO_3$ (2 × 100 mL), and H_2O (2 × 100 mL). The organic layer was dried ($MgSO_4$) and filtered, and the solvents were evaporated in vacuo. Purification of the crude product by flash chromatography (SiO_2, petroleum ether/EtOAc, 4:1) afforded **16** (5.78 g, 10.6 mmol, 85%) as a colorless syrup. TLC (SiO_2): R_f = 0.48 (petroleum ether/EtOAc = 2:1). $[\alpha]_D$ = −2.2 (*c* = 1, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.15, 0.17 [2s, 6 H, $Si(CH_3)_2$], 0.85 (s, 6 H, 2 CH_3), 0.86 [d, ^3J = 6.7 Hz, 6 H, $CH(CH_3)_2$], 1.35 [s, 3 H, $C(CH_3)_2$], 1.37 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH_3), 1.44 (d, $^3J_{\alpha,\beta}$ = 7.5 Hz, 3 H, Ala-β-CH_3), 1.48 [s, 3 H, $C(CH_3)_2$], 1.64 [quint, ^3J = 6.9 Hz, 1 H, $CH(CH_3)_2$], 3.12−3.22 (m, 2 H, 3-H, 5-H), 3.31 (dd, $^3J_{1,2}$ = 7.5, $^3J_{2,3}$ = 9.9 Hz, 1 H, 2-H), 3.64 (dd, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.4 Hz, 1 H, 4-H), 3.73 (t, $^2J_{6,6'}$ = 10.4 Hz, 1 H, 6-H), 3.73 (s, 3 H, OCH_3), 3.84 (dd, $^3J_{5,6'}$ = 5.6, $^2J_{6,6'}$ = 10.8 Hz, 1 H, 6′-H), 4.31 (q, $^3J_{\alpha,\beta}$ = 6.9 Hz, 1 H, Lac-α-H), 4.58 (dq, $^3J_{\alpha,NH} \approx {}^3J_{\alpha,\beta}$ = 8.1 Hz, 1 H, Ala-α-H), 4.59 (d, $^3J_{1,2}$ = 7.5 Hz, 1 H, 1-H), 7.90 (d, $^3J_{\alpha,NH}$ = 7.5 Hz, 1 H, Ala-NH) ppm. FAB MS (positive mode, NBA, glycerol): *m*/*z* = 545 $[M + H]^+$, 567 $[M + Na]^+$. $C_{24}H_{44}N_4O_8Si$ (544.7): calcd. C 52.92, H 8.14, N 10.29; found C 53.14, H 8.16, N 9.74.

Thexyldimethylsilyl 2-Acetamido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-[(2*R*)-propionyl-(L-alanine methyl ester)-2-yl]-β-D-glucopyranoside (17): A stream of H_2S was bubbled through a stirred solution of azide **16** (100 mg, 0.18 mmol) in pyridine (4 mL) and H_2O (1 mL) for 15 min. After 24 h the solvent was removed under vacuum and the residue was stirred for 12 h in a 1:1 mixture of Ac_2O and pyridine (8 mL, v/v). Removal of the solvent in vacuo afforded the crude product, which was purified by flash chromatography (SiO_2, toluene/acetone = 5:1) to give **17** (90 mg, 0.16 mmol, 89%) as a light yellow foam. TLC (SiO_2): R_f = 0.71 (toluene/acetone = 1:1). $[\alpha]_D$ = −18.6 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 0.11, 0.13 [2s, 6 H, $Si(CH_3)_2$], 0.83−0.87 (m, 12 H, 4 CH_3), 1.34−1.39 [m, 6 H, Lac-β-CH_3, $C(CH_3)_2$], 1.44−1.45 (m, 3 H, Ala-β-CH_3), 1.50−1.52 [m, 3 H, $C(CH_3)_2$], 1.59−1.62 [m, 1 H, $CH(CH_3)_2$], 1.93 (s, 3 H, NH*Ac*), 3.28−3.32 (m, 1 H, 5-H), 3.39−3.43 (m, 1 H, 2-H), 3.62 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.3 Hz, 1 H, 4-H), 3.76 (s, 3 H, OCH_3), 3.74−3.78 (m, 1 H, 6-H), 3.85−3.91 (m, 2 H, 3-H, 6′-H), 4.14 (q, $^3J_{\alpha,\beta}$ = 6.7 Hz, 1 H, Lac-α-H), 4.49 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.2 Hz, 1 H, Ala-α-H), 5.00 (d, $^3J_{1,2}$ = 7.8 Hz, 1 H, 1-H), 5.76 (d, $^3J_{NH,2}$ = 8.1 Hz, 1 H, N*H*Ac), 7.29 (d, $^3J_{NH,\alpha}$ = 7.1 Hz, 1 H, Ala-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −3.5, −1.9 [2C, $Si(CH_3)_2$], 18.2, 18.5, 18.5, 19.0, 19.5, 19.9, 20.0 [7C, C*C*H$_3$, Ala-β-C, Lac-β-C, $C(CH_3)_2CH(CH_3)_2$], 23.8 [1C, NHC(O)*C*H$_3$], 24.7 [1C, $C(CH_3)_2CH(CH_3)_2$], 29.1 (1C, C*C*H$_3$), 34.0 [1C, $C(CH_3)_2CH(CH_3)_2$], 48.0 (1C, Ala-α-C), 52.4 (1C, OCH_3), 59.7 (1C, 2-C), 62.2 (1C, 6-C), 67.0 (1C, 5-C), 74.7 (1C, 4-C), 78.1 (1C, Lac-α-C), 79.5 (1C, 3-C), 95.4 (1C, 1-C), 99.3 (1C, *C*CH$_3$), 170.5 [1C, NH*C*(O)CH$_3$], 173.2, 173.5 [2C, C(O)NH, *C*O$_2$CH$_3$] ppm. FAB MS (positive mode, NBA, glycerol): *m*/*z* = 561 $[M + H]^+$, 583 $[M + Na]^+$. $C_{26}H_{48}N_2O_9Si$ (560.8): calcd. C 55.69, H 8.63, N 5.00; found C 55.42, H 8.67, N 4.34.

Thexyldimethylsilyl 2-Acetamido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-[(2*R*)-propionyl-(L-alanine)-2-yl]-β-D-glucopyranoside (18): Saponification of the methyl ester **17** (700 mg, 1.25 mmol) according to Procedure D afforded the free acid **18** (680 mg, 1.25 mmol, quant.) as a glassy, colorless solid. The solid was coevaporated several times with toluene, dried in vacuo, and then used directly in the next step. A sample was purified for analysis by flash chromatography (SiO_2, EtOAc/MeOH = 3:1). TLC (SiO_2): R_f = 0.71 (acetone/AcOH = 98:2). $[\alpha]_D$ = +11.9 (*c* = 1, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$/[D$_4$]MeOH = 10:1): δ = 0.04, 0.06 [2s, 6 H, $Si(CH_3)_2$], 0.76 (2s, 6 H, 2 CH_3), 0.78 [d, ^3J = 7.0 Hz, 6 H, $CH(CH_3)_2$], 1.26−1.33 [m, 9 H, Lac-β-CH_3, Ala-β-CH_3, $C(CH_3)_2$], 1.43 [s, 3 H, $C(CH_3)_2$], 1.54 [quint, ^3J = 6.9 Hz, 1 H, $CH(CH_3)_2$], 1.85 (s, 3 H, NH*Ac*), 3.15−3.25 (m, 1 H, 5-H), 3.53−3.84 (m, 5 H, 2-H, 3-H, 4-H, 6-H, 6′-H), 3.97 (q, $^3J_{\alpha,\beta}$ = 6.8 Hz, 1 H, Lac-α-H), 4.11 (m, 1 H, Ala-α-H), 4.79 (d, $^3J_{1,2}$ = 6.8 Hz, 1 H, 1-H), 7.56 (d, ^3J = 6.9 Hz, 1 H, NH), 7.64 (d, ^3J = 8.2 Hz, 1 H, NH) ppm. $C_{25}H_{46}N_2O_9Si{\cdot}H_2O$ (564.7): calcd. C 53.17, H 8.57, N 4.96; found C 53.06, H 8.17, N 4.26.

1,6-Anhydro-4-*O*-benzyl-2-deoxy-2-iodo-β-D-glucopyranose (20): Bis(tributyltin) oxide (0.61 g, 1.02 mmol) and pulverized, dry mol. sieves (3 Å, 0.8 g) were added to a solution of glucal **19** (0.3 g, 1.27 mmol) in dry MeCN (20 mL), and the mixture was heated under reflux for 3 h. The reaction mixture was then allowed to cool to ambient temperature, iodine was added (0.39 g, 1.52 mmol), and the mixture was stirred for another 45 min. After filtration and removal of the solvent, flash chromatography (SiO_2, petroleum ether/EtOAc = 5:1→3:2) of the residue afforded **20**, which crystallized from petroleum ether/EtOAc (≈ 95:5 v/v) at −50 °C as light yellow crystals (0.41 g, 1.13 mmol, 89%). The spectroscopic data were identical to those reported previously.[53]

1,6-Anhydro-2-azido-4-*O*-benzyl-2-deoxy-β-D-glucopyranose (21): Tetramethyl guanidinium azide (32.1 g, 0.2 mol, Merck) was added to the iodide **20** (10.5 g, 29 mmol) in dry DMF (100 mL). Under an atmosphere of nitrogen, the reaction mixture was stirred at 50 °C (30 min) and then heated to 120 °C (72 h). After removal of the solvent in vacuo, the residue was dissolved in EtOAc (1000 mL) and extracted with H_2O (3 × 200 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated under vacuum. Flash chromatography (SiO_2, toluene/EtOAc = 6:1→5:1) afforded **21** (6.3 g, 22.8 mmol, 79%), which crystallized from toluene as colorless crystals. TLC (SiO_2): R_f = 0.33 (CH_2Cl_2/EtOAc = 9:1). m.p.: 97−98

°C; ref.:[54] m.p.: 96 °C. The analytical data were identical to those reported previously.[54,55]

2-Acetamido-1,6-anhydro-4-*O*-benzyl-2-deoxy-3-*O*-[(1*R*)-1-(methoxycarbonyl)ethyl]-β-D-glucopyranose (23): The azide **22** (110 mg, 0.3 mmol) was transformed into the acetamino derivative as described for compound **17**. Purification of the crude product by flash chromatography (SiO_2, toluene/EtOAc = 1:1) afforded **23** (105 mg, 0.28 mmol, 92%). The spectroscopic and analytical data were identical to those reported previously.[39]

2-Amino-1,6-anhydro-4-*O*-benzyl-3-*O*-[(1*R*)-1-carboxyethyl]-2-deoxy-β-D-glucopyranose 1′,2-Lactam (25): Triphenylphosphane (173 mg, 0.66 mmol) was added to a stirred solution of azide **22** (200 mg, 0.55 mmol) in THF (5 mL) and H_2O (0.5 mL). After 48 h the pH was adjusted with glacial AcOH (pH 5) and the solvent was removed in vacuo. The residue was coevaporated with toluene (3 × 10 mL) and then acetylated (Ac_2O/pyridine = 1:1; v/v, 8 mL, 20 h). The solvent was removed in vacuo and the residue was purified by flash chromatography (SiO_2, toluene/EtOAc = 1:1) to afford lactam **25** (126 mg, 0.41 mmol, 75%) as a colorless solid, which crystallized from toluene. The analytical data were identical to those reported previously.[57]

***tert*-Butyl *N*-Benzyloxycarbonyl-D-isoglutaminate:** The amide **28**[58,59] was synthesized as described for the corresponding L isomer.[60]

Dimethyl (*N*-Benzyloxycarbonyl-L-alanyl)-D-glutamate (29): Dipeptide **29** (8.64 g, 22.7 mmol, 96%) was synthesized from dimethyl D-glutamate (5 g, 23.5 mmol), *N*-benzyloxycarbonyl-L-alanine (5.25 g, 23.5 mmol), and EEDQ (8.73 g, 35.3 mmol) as described for compound **16**. It was isolated as a colorless, amorphous solid. TLC (SiO_2): R_f = 0.23 (petroleum ether/EtOAc = 1:1). $[\alpha]_D$ = −23.6 (c = 0.5, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 1.37 (d, $^3J_{\alpha,\beta}$ = 7.1 Hz, 3 H, Ala-β-CH_3), 1.92−2.04, 2.15−2.25 (2m, 2 H, Glu-β-CH_2), 2.32−2.40 (m, 2 H, Glu-γ-CH_2), 3.65, 3.71 (2s, 6 H, 2 OCH_3), 4.26 (m, 1 H, Glu-α-H), 4.57 (dq, ^3J = 7.9 Hz, 1 H, Ala-α-H), 5.10 (s, 2 H, CH_2Ph), 5.28, 6.80 (2bd, 2 H, 2 NH), 7.28−7.35 (m, 5 H, Ph). MALDI MS (positive mode, DHB, THF): m/z = 382 $[M + H]^+$, 404 $[M + Na]^+$, 420 $[M + K]^+$; calcd. 380.4 for $C_{18}H_{24}N_2O_7$.

Methyl N^{α}-(*N*-Benzyloxycarbonyl-D-isoglutamyl α-methyl ester)-N^{ε}-(*tert*-butyloxycarbonyl)-L-lysinate (30): 1-Methyl *N*-benzyloxycarbonyl-D-glutamate (200 mg, 0.68 mmol) and methyl N^{ε}-(*tert*-butyloxycarbonyl)-L-lysine hydrochloride (195 mg, 0.68 mmol) were coupled according to Procedure B. Purification of the crude product by flash chromatography (SiO_2, toluene/acetone = 1:1) afforded the dipeptide **30** (342 mg, 0.64 mmol, 94%) as a colorless, amorphous solid. TLC (SiO_2): R_f = 0.51 (toluene/acetone = 1:1). $[\alpha]_D$ = +1 (c = 1, MeOH). ^{1}H NMR (250 MHz, [D$_6$]DMSO): δ = 1.18−1.41 (m, 4 H, Lys-γ-CH_2, Lys-δ-CH_2), 1.35 [s, 9 H, C$(CH_3)_3$], 1.50−1.68 (m, 2 H, Lys-β-CH_2), 1.70−2.03 (2m, 2 H, Glu-β-CH_2), 2.21 (t, $^3J_{\beta,\gamma}$ = 7.0 Hz, 2 H, Glu-γ-CH_2), 2.87 (q, ^3J = 6.4 Hz, 2 H, Lys-ε-CH_2), 3.59, 3.62 (2s, 6 H, 2 OCH_3), 4.03, 4.16 (2m, 2 H, Glu-α-H, Lys-α-H), 5.02 (s, 2 H, CH_2Ph), 6.77 (t, $^3J_{\varepsilon,NH}$ = 6.4 Hz, 1 H, Lys-ε-NH), 7.25−7.42 (m, 5 H, Ph), 7.74 (d, $^3J_{\alpha,NH}$ = 8.6 Hz, 1 H, Z-NH), 8.21 (d, $^3J_{\alpha,NH}$ = 7.0 Hz, 1 H, Lys-α-NH) ppm. $C_{26}H_{39}N_3O_9$ (537.6): calcd. C 58.09, H 7.31, N 7.82; found C 58.03, H 7.52, N 7.51.

7-Methyl 1-[2-(Trimethylsilyl)ethyl] (2*S*,6*R*)-N^{α}-(*N*-Benzyloxycarbonyl-D-isoglutamyl α-methyl ester)-N^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate (31a): 1-Methyl *N*-benzyloxycarbonyl-D-glutamate (370 mg, 1.25 mmol) was coupled with compound (*S*,*R*)-**9** (560 mg, 1.04 mmol) according to Procedures A and B. Purification of the product by flash chromatography (SiO_2, toluene/EtOAc = 2:1) afforded dipeptide **31a** (673 mg, 0.99 mmol, 96%) as a colorless syrup. TLC (SiO_2): R_f = 0.75 (toluene/acetone = 1:1). $[\alpha]_D$ = +3.5 (c = 1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 0.01 [s, 9 H, Si$(CH_3)_3$], 0.92 [t, ^3J = 8.4 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 1.32 (m, 2 H, 4-CH_2), 1.36 [s, 9 H, C$(CH_3)_3$], 1.52−1.54, 1.61−1.62 (2m, 4 H, 3-CH_2, 5-CH_2), 1.77, 1.93 (2m, 2 H, Glu-β-CH_2), 2.20 (t, $^3J_{\beta,\gamma}$ = 7.5 Hz, 2 H, Glu-γ-CH_2), 3.59, 3.62 (2s, 6 H, 2 OCH_3), 3.90 (m, 1 H, 6-H), 4.04 (m, 1 H, Glu-α-H), 4.07−4.14 [m, 3 H, 2-H, $OCH_2CH_2Si(CH_3)_3$], 5.02 (m, 2 H, CH_2Ph), 7.17 (d, $^3J_{\alpha,NH}$ = 7.7 Hz, 1 H, Boc-NH), 7.31−7.36 (m, 5 H, Ph), 7.71 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Z-NH), 8.15 (d, $^3J_{\alpha,NH}$ = 7.3 Hz, 1 H, 2-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −1.5 [3C, Si$(CH_3)_3$], 16.8 [1C, $OCH_2CH_2Si(CH_3)_3$], 21.9 (1C, 4-C), 26.6 (1C, Glu-β-C), 28.1 [3C, C$(CH_3)_3$], 30.2, 30.4 (2C, 3-C, 5-C), 31.2 (1C, Glu-γ-C), 51.7, 51.8, 51.9 (2C, 2 OCH_3, 2-C), 53.2 (1C, 6-C), 53.5 (1C, Glu-α-C), 62.4 [1C, $OCH_2CH_2Si(CH_3)_3$], 65.5 (1C, CH_2Ph), 78.2 [1C, C$(CH_3)_3$], 127.1, 127.7, 127.8, 128.3, 136.9 (6C, Ph), 155.5, 156.0 [2C, 2 OC(O)NH], 171.3, 172.1, 172.6, 173.0 [4C, 2 CO_2CH_3, C(O)NH, $CO_2(CH_2)_2Si(CH_3)_3$] ppm. FAB MS (positive mode, NBA, glycerol, $CHCl_3$): m/z = 704 $[M + Na]^+$. $C_{32}H_{51}N_3O_{11}Si$ (681.9): calcd. C 56.37, H 7.54, N 6.16; found C 56.26, H 7.52, N 5.50.

7-Methyl 1-[2-(Trimethylsilyl)ethyl] (2*S*,6*S*)-N^{α}-(*N*-Benzyloxycarbonyl-D-isoglutamyl α-methyl ester)-N^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate (31b): Compound (*S*,*S*)-**9** (230 mg, 0.43 mmol) was hydrogenated according to Procedure A, and then coupled with 1-methyl *N*-benzyloxycarbonyl-D-glutamate (140 mg, 0.47 mmol) (Procedure B). Purification by flash chromatography (SiO_2, toluene/EtOAc = 2:1) afforded **31b** (279 mg, 0.41 mmol, 96%) as a colorless syrup. TLC (SiO_2): R_f = 0.75 (toluene/acetone = 1:1). $[\alpha]_D$ = −6.1 (c = 1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 0.01 [s, 9 H, Si$(CH_3)_3$], 0.92 [t, ^3J = 8.4 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 1.31 (m, 2 H, 4-CH_2), 1.36 [s, 9 H, C$(CH_3)_3$], 1.53−1.60 (m, 4 H, 3-CH_2, 5-CH_2), 1.76, 1.94 (2m, 2 H, Glu-β-CH_2), 2.20 (t, $^3J_{\beta,\gamma}$ = 7.5 Hz, 2 H, Glu-γ-CH_2), 3.59, 3.62 (2s, 6 H, 2 OCH_3), 3.89 (m, 1 H, 6-H), 4.04 (m, 1 H, Glu-α-H), 4.08−4.13 [m, 3 H, 2-H, $OCH_2CH_2Si(CH_3)_3$], 5.02 (m, 2 H, CH_2Ph), 7.17 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Boc-NH), 7.31−7.37 (m, 5 H, Ph), 7.71 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Z-NH), 8.16 (d, $^3J_{\alpha,NH}$ = 7.3 Hz, 1 H, 2-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −1.5 [3C, Si$(CH_3)_3$], 16.7 [1C, $OCH_2CH_2Si(CH_3)_3$], 22.1 (1C, 4-C), 26.6 (1C, Glu-β-C), 28.1 [3C, C$(CH_3)_3$], 30.2, 30.4 (2C, 3-C, 5-C), 31.1 (1C, Glu-γ-C), 51.6 (2C, 2 OCH_3), 51.8 (1C, 2-C), 53.4 (1C, 6-C), 53.5 (1C, Glu-α-C), 62.4 [1C, $OCH_2CH_2Si(CH_3)_3$], 65.5 (1C, CH_2Ph), 78.2 [1C, C$(CH_3)_3$], 127.7, 128.3, 136.8 (6C, Ph), 155.5, 156.0 [2C, 2 OC(O)NH], 171.4, 172.1, 172.6, 173.0 [4C, 2 CO_2CH_3, C(O)NH, $CO_2(CH_2)_2Si(CH_3)_3$] ppm. $C_{32}H_{51}N_3O_{11}Si{\cdot}1.5\ H_2O$ (708.9): calcd. C 54.20, H 7.68, N 5.93; found C 54.41, H 7.73, N 4.95.

7-Methyl 1-[2-(Trimethylsilyl)ethyl] (2*S*,6*R*)-N^{α}-[(*N*-Benzyloxycarbonyl-L-alanyl)-D-isoglutamyl α-methyl ester]-N^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate (32a): The dipeptide **31a** (419 mg, 0.61 mmol) was hydrogenated (Procedure A) and coupled with *N*-benzyloxycarbonyl-L-alanine (170 mg, 0.76 mmol) (Procedure B). Purification of the crude product by flash chromatography (SiO_2, toluene/acetone = 2:1) afforded the tripeptide **32a** (423 mg, 0.56 mmol, 92%) as a colorless foam. TLC (SiO_2): R_f = 0.69 (toluene/acetone = 1:1). $[\alpha]_D$ = −5.6 (c = 2, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 0.01 [s, 9 H, Si$(CH_3)_3$], 0.92 [t, ^3J = 8.3 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 1.21 (d, $^3J_{\alpha,\beta}$ = 7.1 Hz, 3 H, Ala-β-CH_3), 1.31 (m, 2 H, 4-CH_2), 1.36 [s, 9 H, C$(CH_3)_3$], 1.52−1.56,

1.60−1.63 (2m, 4 H, 3-CH_2, 5-CH_2), 1.78−1.81, 1.91−1.93 (2m, 2 H, Glu-β-CH_2), 2.15 (t, $^3J_{\beta,\gamma}$ = 7.4 Hz, 2 H, Glu-γ-CH_2), 3.59, 3.62 (2s, 6 H, 2 OCH_3), 3.90 (m, 1 H, 6-H), 4.08−4.13 [m, 4 H, $OCH_2CH_2Si(CH_3)_3$, Ala-α-H, 2-H], 4.23 (q, $^3J_{\alpha,\beta}$ = 5.8 Hz, 1 H, Glu-α-H), 5.01 (2d, ^2J = 12.3 Hz, 2 H, CH_2Ph), 7.18 (d, $^3J_{\alpha,NH}$ = 7.7 Hz, 1 H, Boc-NH), 7.30 (br. d, 1 H, Z-NH), 7.34 (m, 5 H, Ph), 8.16 (d, $^3J_{\alpha,NH}$ = 7.4 Hz, 1 H, 2-NH), 8.24 (d, $^3J_{\alpha,NH}$ = 7.4 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −1.5 [3C, $Si(CH_3)_3$], 16.7 [1C, $OCH_2CH_2Si(CH_3)_3$], 18.5 (1C, Ala-β-C), 21.9 (1C, 4-C), 27.0 (1C, Glu-β-C), 28.1 [3C, $C(CH_3)_3$], 30.2, 30.3 (2C, 3-C, 5-C), 31.1 (1C, Glu-γ-C), 49.8 (1C, Ala-α-C), 51.6 (1C, Glu-α-C), 51.6 (2C, 2 OCH_3), 51.8 (1C, 2-C), 53.2 (1C, 6-C), 62.4 [1C, $OCH_2CH_2Si(CH_3)_3$], 65.3 (1C, CH_2Ph), 78.1 [1C, $C(CH_3)_3$], 127.7, 128.3, 137.0 (6C, Ph), 154.0, 155.5 [2C, 2 OC(O)NH], 171.3, 172.1 [5C, 2 CO_2CH_3, 2 C(O)NH, $CO_2(CH_2)_2Si(CH_3)_3$] ppm. $C_{35}H_{56}N_4O_{12}Si\cdot 0.3H_2O$ (752.9): calcd. C 55.41, H 7.53, N 7.39; found C 55.36, H 7.61, N 7.04.

7-Methyl 1-[2-(Trimethylsilyl)ethyl] (2*S*,6*S*)-N^{α}-[(*N*-Benzyloxycarbonyl-L-alanyl)-D-isoglutamyl α-methyl ester]-N^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate (32b): Compound **31b** (514 mg, 0.75 mmol) was deprotected according to Procedure A. Peptide coupling (Procedure B) with *N*-benzyloxycarbonyl-L-alanine (202 mg, 0.91 mmol) afforded the tripeptide **32b**, which was purified by flash chromatography (SiO_2, toluene/acetone = 2:1) to give a colorless foam (499 mg, 0.66 mmol, 89%). TLC (SiO_2): R_f = 0.69 (toluene/acetone = 1:1). $[\alpha]_D$ = −13.7 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 0.01 [s, 9 H, $Si(CH_3)_3$], 0.92 [t, ^3J = 8.5 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 1.20 (d, $^3J_{\alpha,\beta}$ = 7.1 Hz, 3 H, Ala-β-CH_3), 1.31 (m, 2 H, 4-CH_2), 1.36 [s, 9 H, $C(CH_3)_3$], 1.54−1.62 (m, 4 H, 3-CH_2, 5-CH_2), 1.79, 1.92 (2m, 2 H, Glu-β-CH_2), 2.16 (t, $^3J_{\beta,\gamma}$ = 7.5 Hz, 2 H, Glu-γ-CH_2), 3.59, 3.61 (2s, 6 H, 2 OCH_3), 3.89 (m, 1 H, 6-H), 4.07−4.22 [m, 4 H, $OCH_2CH_2Si(CH_3)_3$, Ala-α-H, 2-H], 4.23 (q, $^3J_{\alpha,\beta}$ = 5.8 Hz, 1 H, Glu-α-H), 5.01 (2d, ^2J = 10.1 Hz, 2 H, CH_2Ph), 7.20 (d, $^3J_{\alpha,NH}$ = 7.7 Hz, 1 H, Boc-NH), 7.30 (br. d, 1 H, Z-NH), 7.32−7.38 (m, 5 H, Ph), 8.17 (d, $^3J_{\alpha,NH}$ = 7.4 Hz, 1 H, 2-NH), 8.26 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −1.5 [3C, $Si(CH_3)_3$], 16.7 [1C, $OCH_2CH_2Si(CH_3)_3$], 18.5 (1C, Ala-β-C), 22.1 (1C, 4-C), 27.0 (1C, Glu-β-C), 28.1 [3C, $C(CH_3)_3$], 30.2, 30.4 (2C, 3-C, 5-C), 31.1 (1C, Glu-γ-C), 49.8 (1C, Ala-α-C), 51.6 (1C, Glu-α-C), 51.7 (2C, 2 OCH_3), 51.8 (1C, 2-C), 53.4 (1C, 6-C), 62.5 [1C, $OCH_2CH_2Si(CH_3)_3$], 65.3 (1C, CH_2Ph), 78.2 [1C, $C(CH_3)_3$], 127.7, 127.8, 128.3, 137.0 (6C, Ph), 155.5 [2C, 2 OC(O)NH], 171.4, 172.2, 172.7, 173.1 [5C, 2 CO_2CH_3, 2 C(O)NH, $CO_2(CH_2)_2Si(CH_3)_3$] ppm. $C_{35}H_{56}N_4O_{12}Si$ (752.9): calcd. C 55.83, H 7.41, N 7.44; found C 55.89, H 7.27, N 7.63.

Methyl [7-Methyl (2*S*,6*R*)-N^{α}-Benzyloxycarbonyl-N^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelyl]-D-alaninate (34): TBAF in THF (1 M, 0.7 mL, 0.7 mmol) was added to a stirred solution of the β-silyl ester (*S*,*R*)-**9** (350 mg, 0.65 mmol) in dry THF (35 mL). The reaction was monitored by TLC until consumption of the starting material was complete. After neutralization of the reaction mixture (Amberlite, IR 120 H^+), the solution was filtered, concentrated, and flushed through a short column (SiO_2, EtOAc/MeOH = 3:1). The eluent was concentrated and dried, and the obtained crude **33** was directly coupled with D-alanine methyl ester hydrochloride (100 mg, 0.72 mmol) according to Procedure B. Purification of the crude product by flash chromatography (SiO_2, petroleum ether/EtOAc = 1:1) afforded **34** (313 mg, 0.60 mmol, 92%) as a colorless syrup. TLC (SiO_2): R_f = 0.63 (toluene/acetone = 1:1). $[\alpha]_D$ = +11.7 (*c* = 1, MeOH). ^{1}H NMR (250 MHz, [D$_6$]DMSO): δ = 1.25 (d, $^3J_{\alpha,\beta}$ = 7.2 Hz, 3 H, Ala-β-CH_3), 1.32 (m, 2 H, 4-CH_2), 1.36 [s, 9 H, $C(CH_3)_3$], 1.45−1.65 (m, 4 H, 3-CH_2, 5-CH_2), 3.59, 3.60 (2s, 6 H, 2 OCH_3), 3.83−3.92, 3.97−4.05 (2m, 2 H, 2-H, 6-H), 4.25 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.2 Hz, 1 H, Ala-α-H), 5.01 (s, 2 H, CH_2Ph), 7.21 (d, $^3J_{NH,\alpha}$ = 7.7 Hz, 1 H, NH), 7.25−7.39 (m, 6 H, Ph, NH), 8.34 (d, $^3J_{NH,\alpha}$ = 7.3 Hz, 1 H, NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = 17.1 (1C, Ala-β-C), 21.9 (1C, 4-C), 27.8, 28.1 [3C, $C(CH_3)_3$], 30.3, 31.7 (2C, 3-C, 5-C), 47.4 (1C, Ala-α-C), 51.6, 51.8 (2C, 2 OCH_3), 53.5, 54.0 (2C, 2-C, 6-C), 65.3 (1C, CH_2Ph), 78.1 [1C, $C(CH_3)_3$], 127.0, 127.6, 127.7, 128.3, 137.0 (6C, Ph), 155.5, 155.8 [2C, 2 OC(O)NH], 171.6, 172.8, 173.1 [3C, 2 CO_2CH_3, C(O)NH]. MALDI MS (positive mode, DHB, THF): *m*/*z* = 546 $[M + Na]^+$; calcd. 523.6 for $C_{25}H_{37}N_3O_9$.

Methyl [7-Methyl (2*S*,6*R*)-N^{α}-(*N*-Benzyloxycarbonyl-D-isoglutamyl α-methyl ester)-N^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelyl]-D-alaninate (35): The dipeptide **34** (200 mg, 0.38 mmol) was hydrogenated (Procedure A) and coupled with 1-methyl *N*-benzyloxycarbonyl-D-glutamate (218 mg, 0.42 mmol) according to Procedure B. Flash chromatography (SiO_2, toluene/EtOAc = 2:1) afforded the tripeptide **35** (217 mg, 0.33 mmol, 86%) as a colorless syrup. TLC (SiO_2): R_f = 0.39 (toluene/acetone = 1:1). $[\alpha]_D$ = +11.1 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 1.25 (t, $^3J_{\alpha,\beta}$ = 7.2 Hz, 3 H, Ala-β-CH_3), 1.31 (m, 2 H, 4-CH_2), 1.36 [s, 9 H, $C(CH_3)3$], 1.42−1.45, 1.53−1.60 (2m, 4 H, 3-CH_2, 5-CH_2), 1.76, 1.93 (2m, 2 H, Glu-β-CH_2), 2.21 (t, $^3J_{\beta,\gamma}$ = 7.1 Hz, 2 H, Glu-γ-CH_2), 3.59, 3.60, 3.62 (3s, 9 H, 3 OCH_3), 3.87 (m, 1 H, 6-H), 4.02 (m, 1 H, Glu-α-H), 4.24−4.28 (m, 2 H, 2-H, Ala-α-H), 5.02 (m, 2 H, CH_2Ph), 7.15 (d, $^3J_{\alpha,NH}$ = 7.7 Hz, 1 H, Boc-NH), 7.29−7.37 (m, 5 H, Ph), 7.71 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Z-NH), 7.89 (d, $^3J_{\alpha,NH}$ = 8.3 Hz, 1 H, 2-NH), 8.30 (d, $^3J_{\alpha,NH}$ = 7.2 Hz, 1 H, Ala-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = 17.0 (1C, Ala-β-CH_2), 21.7 (1C, 4-C), 26.8 (1C, Glu-β-C), 28.1 [3C, $C(CH_3)_3$], 30.3, 31.9 (2C, 3-C, 5-C), 31.3 (1C, Glu-γ-C), 47.4 (1C, Ala-α-C), 51.6, 51.8 (4C, 3 OCH_3, 2-C), 53.5 (2C, 6-C, Glu-α-C), 65.5 (1C, CH_2Ph), 78.1 [1C, $C(CH_3)_3$], 127.7, 127.8, 128.3, 136.8 (6C, Ph), 156.0 [2C, 2 OC(O)NH], 171.0, 171.3, 172.6, 172.8, 173.1 [5C, 3 CO_2CH_3, 2 C(O)NH] ppm. FAB MS (positive mode, NBA, glycerol): *m*/*z* = 667 $[M + H]^+$, 689 $[M + Na]^+$. $C_{31}H_{46}N_4O_{12}$ (666.7): calcd. C 55.85, H 6.95, N 8.40; found C 55.81, H 7.01, N 8.27.

Thexyldimethylsilyl 2-Azido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-[(2*R*)-propionyl-(L-alanyl-D-glutamic acid dimethyl ester)-2-yl]-β-D-glucopyranoside (36): The *Z*-protected dipeptide **29** (0.95 g, 3.3 mmol) was hydrogenated (Procedure A) and then coupled with **15** (1.28 g, 2.8 mmol) and EEDQ (1.03 g, 4.19 mmol) as described for compound **16**. Purification by flash chromatography (SiO_2, toluene/acetone = 7:1) afforded compound **36** (1.25 g, 1.82 mmol, 65%) as a colorless syrup. TLC (SiO_2): R_f = 0.78 (toluene/acetone = 1:1). $[\alpha]_D$ = −25.3 (*c* = 1, $CHCl_3$). ^{1}H NMR (250 MHz, $CDCl_3$): δ = 0.14, 0.17 [2s, 6 H, $Si(CH_3)_2$], 0.84 (s, 6 H, 2 CH_3), 0.86 [d, ^3J = 6.1 Hz, 6 H, $CH(CH_3)_2$], 1.36 [s, 3 H, $C(CH_3)_2$], 1.39 (d, $^3J_{\alpha,\beta}$ = 6.9 Hz, 3 H, Lac-β-CH_3), 1.41 (d, $^3J_{\alpha,\beta}$ = 7.1 Hz, 3 H, Ala-β-CH_3), 1.48 [s, 3 H, $C(CH_3)_2$], 1.63 [m, ^3J = 6.8 Hz, 1 H, $CH(CH_3)_2$], 1.89−2.03, 2.13−2.29 (2m, 2 H, Glu-β-CH_2), 2.33−2.48 (m, 2 H, Glu-γ-CH_2), 3.11−3.22 (m, 2 H, 3-H, 5-H), 3.30 (dd, $^3J_{1,2}$ = 7.5, $^3J_{2,3}$ = 9.9 Hz, 1 H, 2-H), 3.64 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.6 Hz, 1 H, 4-H), 3.65, 3.70 (2s, 6 H, 2 OCH_3), 3.74 (t, $^2J_{6,6'}$ = 10.8, $^3J_{5,6}$ = 10.2 Hz, 1 H, 6-H), 3.84 (dd, $^2J_{6,6'}$ = 10.8, $^3J_{5,6'}$ = 5.5 Hz, 1 H, 6′-H), 4.34 (q, $^3J_{\alpha,\beta}$ = 6.9 Hz, 1 H, Lac-α-H), 4.46 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.1 Hz, 1 H, Ala-α-H), 4.53−4.60 (m, 1 H, Glu-α-H), 4.60 (d, $^3J_{1,2}$ = 7.5 Hz, 1 H, 1-H), 7.01 (d, $^3J_{NH,\alpha}$ = 8.0 Hz, 1 H, Glu-NH), 7.76 (d, $^3J_{NH,\alpha}$ = 7.1 Hz, 1 H, Ala-NH) ppm. EI MS (195 °C): *m*/*z* = 602 [M − thexyl]$^+$, 656 [M −

$OCH_3]^+$, 672 [M − $CH_3]^+$, 687 $[M]^+$; calcd. 687.9 for $C_{30}H_{53}N_5O_{11}Si$.

Thexyldimethylsilyl 2-Acetamido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-[(2*R*)-propionyl-(L-alanyl-D-glutamic acid dimethyl ester)-2-yl]-β-D-glucopyranoside (37). (a) From 36: The reduction and acetylation of azide **36** (670 mg, 0.97 mmol) was performed as described for compound **17**. Flash chromatography (SiO_2, toluene/acetone = 5:2) afforded the acetamide **37** (585 mg, 0.83 mmol, 85%) as a colorless foam.

(b) From 18: The Z-protected dimethyl glutamate (100 mg, 0.26 mmol) was hydrogenated (Procedure A) and coupled with the free acid **18** (156 mg, 0.29 mmol) according to Procedure B. Extractive workup and purification of the crude product by flash chromatography (SiO_2, toluene/acetone = 5:2) afforded **37** (168 mg, 0.24 mmol, 92%) as a colorless foam. TLC (SiO_2): R_f = 0.34 (toluene/acetone = 3:2). $[\alpha]_D$ = −2.6 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 0.08, 0.10 [2s, 6 H, $Si(CH_3)_2$], 0.81−0.85 (m, 12 H, 4 CH_3), 1.34−1.41 [m, 9 H, Lac-β-CH_3, Ala-β-CH_3, $C(CH_3)_2$], 1.48 [s, 3 H, $C(CH_3)_2$], 1.56−1.61 [m, 1 H, $CH(CH_3)_2$], 1.92 (s, 3 H, NH*Ac*), 1.97−2.03, 2.18−2.24 (2m, 2 H, Glu-β-CH_2), 2.34−2.41 (m, 2 H, Glu-γ-CH_2), 3.27−3.32 (m, 2 H, 2-H, 5-H), 3.59 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.1 Hz, 1 H, 4-H), 3.66, 3.72 (2s, 6 H, 2 OCH_3), 3.74−3.76 (m, 1 H, 6-H), 3.83−3.86 (dd, $^2J_{6,6'}$ = 10.8, $^3J_{5,6}$ = 5.4 Hz, 1 H, 6′-H), 3.95 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 9.1 Hz, 1 H, 3-H), 4.15 (q, $^3J_{\alpha,\beta}$ = 6.7 Hz, 1 H, Lac-α-H), 4.40 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.0 Hz, 1 H, Ala-α-H), 4.55−4.59 (m, 1 H, Glu-α-H), 5.04 (d, $^3J_{1,2}$ = 7.8 Hz, 1 H, 1-H), 6.10 (d, $^3J_{NH,2}$ = 7.8 Hz, 1 H, N*H*Ac), 6.97 (d, $^3J_{NH,\alpha}$ = 7.8 Hz, 1 H, Glu-NH), 7.29 (d, $^3J_{NH,\alpha}$ = 7.0 Hz, 1 H, Ala-NH) ppm. ^{13}C NMR (150.8 MHz, $CDCl_3$): δ = −3.5, −1.9 [2C, $Si(CH_3)_2$], 17.9, 18.5, 19.0, 19.5, 19.9, 20.0 [7C, C*C*H_3, Ala-β-C, Lac-β-C, $C(CH_3)_2CH(CH_3)_2$], 23.8 [1C, NHC(O)*C*H_3], 24.7 [1C, $C(CH_3)_2CH(CH_3)_2$], 27.0 (1C, Glu-β-C), 29.1 (1C, C*C*H_3), 29.9 (1C, Glu-γ-C), 34.0 [1C, $C(CH_3)_2CH(CH_3)_2$], 48.9 (1C, Ala-α-C), 51.7 (1C, Glu-α-C), 51.9, 52.6 (2C, 2 OCH_3), 59.9 (1C, 2-C), 62.2 (1C, 6-C), 66.7 (1C, 5-C), 74.9 (1C, 4-C), 77.9 (1C, Lac-α-C), 79.2 (1C, 3-C), 95.1 (1C, 1-C), 99.3 (1C, *C*CH_3), 170.8 [1C, NH*C*(O)CH_3], 172.0, 172.2, 173.1, 173.8]4C, 2 C(O)NH, 2 *C*O_2CH_3] ppm. $C_{32}H_{57}N_3O_{12}Si$ (703.9): calcd. C 54.60, H 8.16, N 5.97; found C 54.27, H 8.21, N 6.02.

Ammonium *N*-Acetylmuramyl-L-alanine (38): The free acid **18** (127 mg, 0.23 mmol) was treated with TFA/dioxane/H_2O (15 mL) according to Procedure E. The crude product was purified by gel chromatography (t_R = 46.2 min) to afford **38** (80 mg, 0.21 mmol, 90%) as a light yellow lyophilizate (from water). TLC (RP-18): R_f = 0.83 (MeCN/H_2O/TFA = 6:1:1). $[\alpha]_D$ = +18.2 (*c* = 0.5, H_2O). ^{1}H NMR (600 MHz, [D$_6$]DMSO + TFA): δ (α anomer) = 1.20−1.30 (m, 6 H, Lac-β-CH_3, Ala-β-CH_3), 1.79 (s, 3 H, NH*Ac*), 3.27 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.2 Hz, 1 H, 4-H), 3.44 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 8.8 Hz, 1 H, 3-H), 3.51 (dd, $^3J_{5,6}$ = 5.7, $^2J_{6,6'}$ = 12.2 Hz, 1 H, 6-H), 3.59−3.65 (m, 3 H, 2-H, 5-H, 6′-H), 4.19−4.23 (m, 1 H, Ala-α-H), 4.31 (q, $^3J_{\alpha,\beta}$ = 6.7 Hz, 1 H, Lac-α-H), 4.42 (d, $^3J_{1,2}$ = 8.2 Hz, 0.9 H, 1-H$_\beta$), 5.01 (d, $^3J_{1,2}$ = 3.4 Hz, 0.1 H, 1-H$_\alpha$), 7.70 (d, $^3J_{\alpha,NH}$ = 7.5 Hz, 1 H, Ala-NH), 8.09 (d, $^3J_{2,NH}$ = 7.5 Hz, 1 H, N*H*Ac) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO + TFA): δ = 17.4 (1C, Ala-β-C), 19.2 (1C, Lac-β-C), 22.8 [1C, NHC(O)*C*H_3], 47.4 (1C, Ala-α-C), 53.8 (1C, 2-C), 61.0 (1C, 6-C), 70.3 (1C, 4-C), 72.4 (1C, 5-C), 76.2 (1C, Lac-α-C), 78.7 (1C, 3-C), 90.6 (1C, 1-C), 169.8, 174.0 [3C, OC(O)NH, NH*C*(O)CH_3, CO_2H] ppm. FAB MS (positive mode, glycerol, DMSO): *m*/*z* = 365 [M − NH_4^+ + $H^+]^+$, 387 [M − NH_4^+ + $Na^+]^+$; calcd. 381.4 for $C_{14}H_{27}N_3O_9$.

Diammonium *N*-Acetyl-muramyl-L-alanyl-D-glutamate (39): A solution of **37** (70 mg, 99 μmol) in dioxane/MeOH (15 mL) was saponified with 1 M LiOH according to Procedure D. The residue was treated with TFA/dioxane/H_2O (10 mL, Procedure E) to remove the remaining protecting groups. Purification of the crude product by gel chromatography (t_R = 43.6 min) afforded **39** (39 mg, 74 μmol, 71%) as a colorless lyophilizate (from water). TLC (RP-18): R_f = 0.79 (MeCN/H_2O/TFA = 6:1:1). $[\alpha]_D$ = +22.8 (*c* = 0.5, H_2O). ^{1}H NMR (600 MHz, [D$_6$]DMSO + TFA): δ (α anomer) = 1.18−1.25 (m, 6 H, Ala-β-CH_3, Lac-β-CH_3), 1.76 (m, 1 H, Glu-β-CH_2), 1.78 (s, 3 H, NH*Ac*), 1.98 (m, 1 H, Glu-β-CH_2), 2.24 (m, 2 H, Glu-γ-CH_2), 3.25 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.2 Hz, 1 H, 4-H), 3.45 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 8.9 Hz, 1 H, 3-H), 3.50 (dd, $^3J_{5,6}$ = 5.8, $^2J_{6,6'}$ = 12.2 Hz, 1 H, 6-H), 3.59−3.61 (m, 2 H, 5-H, 6′-H), 3.66−3.67 (m, 1 H, 2-H), 4.20−4.23 (m, 1 H, Glu-α-H), 4.28 (q, $^3J_{\alpha,\beta}$ = 6.7 Hz, 1 H, Lac-α-H), 4.33−4.34 (m, 1 H, Ala-α-H), 4.97 (d, $^3J_{1,2}$ = 3.3 Hz, 1 H, 1-H), 7.58 (d, $^3J_{\alpha,NH}$ = 7.8 Hz, 1 H, Ala-NH), 8.02 (d, $^3J_{2,NH}$ = 7.9 Hz, 1 H, N*H*Ac), 8.22 (d, $^3J_{\alpha,NH}$ = 8.0 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO + TFA): δ = 19.07, 19.13 (2C, Ala-β-C, Lac-β-C), 22.7 [1C, NHC(O)*C*H_3], 26.6 (1C, Glu-β-C), 30.0 (1C, Glu-γ-C), 47.8 (1C, Ala-α-C), 51.1 (1C, Glu-α-C), 53.7 (1C, 2-C), 61.0 (1C, 6-C), 70.2 (1C, 4-C), 72.4 (1C, 5-C), 76.4 (1C, Lac-α-C), 78.9 (1C, 3-C), 90.7 (1C, 1-C), 196.6, 172.2, 172.7, 173.2, 173.7 [5C, NH*C*(O)CH_3, 2 C(O)NH, 2 CO_2H] ppm. FAB MS (positive mode, glycerol, DMSO): *m*/*z* = 494 [M − $2NH_4^+$ + $3H^+]^+$, 516 [M − $2NH_4^+$ + $2H^+$ + $Na^+]^+$, 626 [M − $2NH_4^+$ + $2H^+$ + $Cs^+]^+$; calcd. 527.5 for $C_{19}H_{37}N_5O_{12}$.

Thexyldimethylsilyl 2-Acetamido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-{(2*R*)-propionyl-[L-alanyl-D-isoglutamine γ-*tert*-butyl ester]-2-yl}-β-D-glucopyranoside (40): The glutamine **28** (91 mg, 0.27 mmol) was hydrogenated (Procedure A) and coupled with the free acid **18** (148 mg, 0.27 mmol) according to Procedure B. Flash chromatography (SiO_2, toluene/acetone = 1:1) afforded **40** (176 mg, 0.24 mmol, 89%) as a colorless solid. TLC (SiO_2): R_f = 0.58 (EtOAc/MeOH = 9:1). $[\alpha]_D$ = −3.7 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 0.07, 0.08 [2s, 6 H, $Si(CH_3)_2$], 0.76 (s, 6 H, 2 CH_3), 0.80 [d, ^3J = 7.2 Hz, 6 H, $CH(CH_3)$2], 1.20 (d, $^3J_{\alpha,\beta}$ = 6.6 Hz, 3 H, Lac-β-CH_3), 1.25 (d, $^3J_{\alpha,\beta}$, 3 H, Ala-β-CH_3), 1.31 [s, 3 H, $C(CH_3)_2$], 1.37 [s, 9 H, $C(CH_3)_3$], 1.45 [s, 3 H, $C(CH_3)_2$], 1.53 [quint, ^3J = 7.2 Hz, 1 H, $CH(CH_3)_2$], 1.54−1.71 (m, 1 H, Glu-β-CH_2), 1.76 (s, 3 H, NH*Ac*), 1.86−1.95 (m, 1 H, Glu-β-CH_2), 2.17 (t, $^3J_{\beta,\gamma}$ = 8.2 Hz, 2 H, Glu-γ-CH_2), 3.18−3.21 (m, 1 H, 5-H), 3.41 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 9.4 Hz, 1 H, 3-H), 3.60 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.2 Hz, 1 H, 4-H), 3.64−3.68 (m, 1 H, 2-H), 3.72 (t, $^3J_{6,6'}$ = 10.8, $^3J_{5,6}$ = 10.3 Hz, 1 H, 6-H), 3.76 (dd, $^2J_{6,6'}$ = 10.8, $^3J_{5,6'}$ = 6.0 Hz, 1 H, 6′-H), 3.97 (q, $^3J_{\alpha,\beta}$ = 6.6 Hz, 1 H, Lac-α-H), 4.10−4.14 (m, 1 H, Glu-α-H), 4.23 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 6.6 Hz, 1 H, Ala-α-H), 4.63 (d, $^3J_{1,2}$ = 7.9 Hz, 1 H, 1-H), 7.06 [s, 1 H, C(O)NH_2], 7.24 (d, $^3J_{NH,\alpha}$ = 6.8 Hz, 1 H, Ala-NH), 7.28 [s, 1 H, C(O)NH_2], 7.83 (d, $^3J_{2,NH}$ = 9.3 Hz, 1 H, N*H*Ac), 8.06 (d, $^3J_{NH,\alpha}$ = 8.2 Hz, 1 H, Glu-NH) ppm. FAB MS (positive mode, NBA, glycerol, dioxane): *m*/*z* = 731 [M + $H]^+$, 753 [M + $Na]^+$; calcd. 731.0 for $C_{34}H_{62}N_4O_{11}Si$.

Ammonium *N*-Acetyl-muramyl-L-alanyl-D-isoglutaminate (41): Compound **40** (70 mg, 96 μmol) was treated with TFA/dioxane/H_2O (10 mL) according to Procedure E and then purified by gel chromatography (t_R = 49.8 min). To remove remaining minor impurities, the crude product was subjected to HPLC (flow rate: 10 mL/min; A: 0.1% TFA, B: MeCN + 0.1% TFA, gradient: 0−10 min: 99% A, 10−30 min: 99−90% A, 30−40 min: 90−5% A; detection: UV 230 nm). The product eluted in two fractions (t_R = 14.9 min; t_R = 24.2 min), which were identified by MALDI-MS and NMR spectroscopy. Repeated lyophilization from NH_4HCO_3 buffer (30 mM) and H_2O afforded **41** (33 mg, 65 μmol, 68%) as a

light yellow lyophilizate. TLC (RP18): R_f = 0.37 (MeCN/H_2O/TFA = 8:1:1). $[\alpha]_D$ = +20.2 (*c* = 0.5, H_2O). ^1H NMR (600 MHz, [D_6]DMSO + TFA): δ (α anomer) = 1.22 (d, $^3J_{\alpha,\beta}$ = 7.0 Hz, 3 H, Ala-β-CH_3), 1.24 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH_3), 1.70, 1.95 (2m, 2 H, Glu-β-CH_2), 1.78 (s, 3 H, NH*Ac*), 2.20 (t, $^3J_{\beta,\gamma}$ = 7.8 Hz, 2 H, Glu-γ-CH_2), 3.26 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.2 Hz, 1 H, 4-H), 3.44 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 8.9 Hz, 1 H, 3-H), 3.50 (dd, $^3J_{5,6}$ = 5.5, $^2J_{6,6'}$ = 12.2 Hz, 1 H, 6-H), 3.59−3.61 (m, 2 H, 5-H, 6′-H), 3.67 (m, 1 H, 2-H), 4.14−4.17 (m, 1 H, Glu-α-H), 4.26−4.28 (m, 2 H, Lac-α-H, Ala-α-H), 4.97 (d, $^3J_{1,2}$ = 3.1 Hz, 1 H, 1-H), 7.00, 7.28 [2s, 2 H, C(O)NH_2], 7.61 (d, $^3J_{\alpha,NH}$ = 6.9 Hz, 1 H, Ala-NH), 8.00 (d, $^3J_{2,NH}$ = 7.9 Hz, 1 H, N*H*Ac), 8.10 (d, $^3J_{\alpha,NH}$ = 8.2 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D_6]DMSO + TFA): δ = 18.3 (1C, Ala-β-C), 19.1 (1C, Lac-β-C), 22.7 [1C, NHC(O)*C*H_3], 27.1 (1C, Glu-β-C), 30.1 (1C, Glu-γ-C), 48.2 (1C, Ala-α-C), 51.7 (1C, Glu-α-C), 53.6 (1C, 2-C), 60.9 (1C, 6-C), 70.0 (1C, 4-C), 72.3 (1C, 5-C), 76.2 (1C, Lac-α-C), 78.8 (1C, 3-C), 90.6 (1C, 1-C), 169.5, 172.1, 173.1, 173.8 [5C, NH*C*(O)CH_3, 2 C(O)NH, C(O)NH_2, CO_2H] ppm. FAB MS (positive mode, glycerol, AcOH/H_2O = 1:1): *m*/*z* = 493 [M − NH_4^+ + H^+]$^+$, 515 [M − NH_4^+ + Na^+]$^+$; calcd. 509.5 for $C_{19}H_{35}N_5O_{11}$.

Thexyldimethylsilyl 2-Acetamido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-{(2*R*)-propionyl-[L-alanyl-D-isoglutamyl α-methyl ester-N^{ε}-(*tert*-butyloxycarbonyl)-D-lysine α-methyl ester]-2-yl}-β-L-glucopyranoside (42): The dipeptide **30** (145 mg, 0.27 mmol) was coupled with the free acid **18** (148 mg, 0.27 mmol) according to Procedures A and B. Purification of the crude product by flash chromatography (SiO_2, toluene/acetone = 1:1) afforded **42** (210 mg, 0.23 mmol, 85%) as a colorless solid. TLC (SiO_2): R_f = 0.34 (toluene/acetone = 1:1). $[\alpha]_D$ = −3.3 (*c* = 1, MeOH). ^1H NMR (600 MHz, [D_6]DMSO): δ = 0.07, 0.08 [2s, 6 H, Si(CH_3)$_2$], 0.76 (s, 6 H, 2 CH_3), 0.80 [d, ^3J = 6.8 Hz, 6 H, CH(C*H*$_3$)$_2$], 1.13−1.26 (m, 8 H, Lac-β-CH_3, Ala-β-CH_3, Lys-γ-CH_2), 1.30 [s, 3 H, C(CH_3)$_2$], 1.31−1.34 (m, 2 H, Lys-δ-CH_2), 1.35 [s, 9 H, C(CH_3)$_3$], 1.46 [s, 3 H, C(CH_3)$_2$], 1.52−1.55 [m, 2 H, C*H*(CH_3)$_2$, Lys-β-CH_2], 1.63 (m, 1 H, Lys-β-CH_2), 1.75 (s, 3 H, NH*Ac*), 1.92 (m, 2 H, Glu-β-CH_2), 2.16 (t, $^3J_{\beta,\gamma}$ = 7.8 Hz, 2 H, Glu-γ-CH_2), 2.85−2.87 (m, 2 H, Lys-ε-CH_2), 3.19−3.22 (m, 1 H, 5-H), 3.41 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 8.6 Hz, 1 H, 3-H), 3.59−3.61 (m, 1 H, 4-H), 3.60, 3.62 (2s, 6 H, 2 OCH_3), 3.65 (m, 1 H, 2-H), 3.72 (t, $^2J_{6,6'} \approx {}^3J_{5,6}$ = 10.3 Hz, 1 H, 6-H), 3.74−3.77 (m, 1 H, 6′-H), 3.98 (q, $^3J_{\alpha,\beta}$ = 6.6 Hz, 1 H, Lac-α-H), 4.16 (m, 1 H, Lys-α-H), 4.21 (m, 1 H, Glu-α-H), 4.32 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.3 Hz, 1 H, Ala-α-H), 4.62 (d, $^3J_{1,2}$ = 8.0 Hz, 1 H, 1-H), 6.74 (br. t, 1 H, Lys-ε-NH), 7.21 (d, $^3J_{NH,\alpha}$ = 7.8 Hz, 1 H, Ala-NH), 7.80 (d, $^3J_{2,NH}$ = 9.6 Hz, 1 H, N*H*Ac), 8.18 (d, $^3J_{NH,\alpha}$ = 7.8 Hz, 1 H, Lys-α-NH), 8.37 (d, $^3J_{NH,\alpha}$ = 7.8 Hz, 1 H, Glu-NH) ppm. FAB MS (positive mode, NBA, glycerol, dioxane): *m*/*z* = 932 [M + H]$^+$, 954 [M + Na]$^+$; calcd. 932.2 for $C_{43}H_{77}N_5O_{15}Si$.

Ammonium *N*-Acetyl-muramyl-L-alanyl-(D-isoglutamyl)-L-lysine (43): Compound **42** (69 mg, 74 μmol) was dissolved in dioxane/MeOH (10 mL) and saponified with 1 M LiOH according to Procedure D. The residue was treated with TFA/dioxane/H_2O (10 mL) to remove the remaining protecting groups (Procedure E). The crude product was purified by gel chromatography (t_R = 41.4 min), followed by HPLC as described for **41**. The product eluted in two fractions (t_R = 25.0 min; t_R = 28.4 min), which were lyophilized repeatedly from NH_4HCO_3 buffer (30 mM) and H_2O to afford **43** (30 mg, 47 μmol, 64%) as a light yellow lyophilizate. TLC (RP-18): R_f = 0.44 (MeCN/H_2O/TFA = 8:1:1). $[\alpha]_D$ = +5.6 (*c* = 0.5 H_2O). ^1H NMR (600 MHz, [D_6]DMSO + TFA): δ (α anomer) = 1.22 (d, $^3J_{\alpha,\beta}$ = 7.0 Hz, 3 H, Ala-β-CH_3), 1.25 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH_3), 1.33 (m, 2 H, Lys-γ-CH_2), 1.50−1.55 (m, 3 H, Lys-β-CH_2, Lys-δ-CH_2), 1.70 (m, 1 H, Lys-β-CH_2), 1.75−1.79 (m, 1 H, Glu-β-CH_2), 1.79 (s, 3 H, NH*Ac*), 1.96 (m, 1 H, Glu-β-CH_2), 2.18 (t, $^3J_{\beta,\gamma}$ = 7.7 Hz, 2 H, Glu-γ-CH_2), 2.75 (m, 2 H, Lys-ε-CH_2), 3.25 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.1 Hz, 1 H, 4-H), 3.46 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 8.9 Hz, 1 H, 3-H), 3.51 (dd, $^3J_{5,6}$ = 5.5, $^2J_{6,6'}$ = 12.0 Hz, 1 H, 6-H), 3.60−3.62 (m, 2 H, 5-H, 6′-H), 3.69 (m, 1 H, 2-H), 4.15−4.19 (m, 2 H, Glu-α-H, Lys-α-H), 4.27 (q, $^3J_{\alpha,\beta}$ = 6.6 Hz, 1 H, Lac-α-H), 4.35−4.38 (m, 1 H, Ala-α-H), 4.96 (d, $^3J_{1,2}$ = 3.5 Hz, 1 H, 1-H), 7.56 (d, $^3J_{\alpha,NH}$ = 7.9 Hz, 1 H, Ala-NH), 7.63 (s, 3 H, Lys-ε-NH_3^+), 8.03 (d, $^3J_{2,NH}$ = 8.1 Hz, 1 H, N*H*Ac), 8.07 (d, $^3J_{\alpha,NH}$ = 7.9 Hz, 1 H, Lys-α-NH), 8.25 (d, $^3J_{\alpha,NH}$ = 7.8 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D_6]DMSO + TFA): δ = 19.1, 19.2 (2C, Ala-β-C, Lac-β-C), 22.5 (1C, Lys-γ-C), 22.7 [1C, NHC(O)*C*H_3], 26.7 (1C, Lys-δ-C), 27.4 (1C, Glu-β-C), 30.6 (1C, Lys-β-C), 31.6 (1C, Glu-γ-C), 38.9 (1C, Lys-ε-C), 47.7 (1C, Ala-α-C), 51.7 (1C, Glu-α-C), 53.8 (1C, 2-C), 61.1 (1C, 6-C), 70.0 (1C, 4-C), 72.4 (1C, 5-C), 76.5 (1C, Lac-α-C), 78.9 (1C, 3-C), 90.8 (1C, 1-C), 169.8, 171.6, 172.7, 173.3, 173.8 [6C, NH*C*(O)CH_3, 3 C(O)NH, 2 CO_2H] ppm. FAB MS (positive mode, glycerol, AcOH/H_2O = 1:1): *m*/*z* = 622 [M − NH_4^+ + H^+]$^+$, 644 [M − NH_4^+ + Na^+]$^+$; calcd. 638.7 for $C_{25}H_{46}N_6O_{13}$.

Thexyldimethylsilyl 2-Acetamido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-{(2*R*)-propionyl-[L-alanyl-(D-isoglutamyl α-methyl ester)-(7-methyl)-1-(2-trimethylsilylethyl) (2*S*,6*R*)-N^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate]-2-yl}-β-D-glucopyranoside (44): The dipeptide **31a** (75 mg, 0.11 mmol) was hydrogenated (Procedure A) and coupled with the free acid **18** (58 mg, 0.11 mmol) (Procedure B). Purification of the crude product by flash chromatography (SiO_2, toluene/acetone = 1:1) afforded **44** (99 mg, 0.09 mmol, 84%) as a colorless, waxy solid. TLC (SiO_2): R_f = 0.46 (toluene/acetone = 1:1). $[\alpha]_D$ = −6.1 (*c* = 1, MeOH). ^1H NMR (600 MHz, [D_6]DMSO): δ = 0.01 [s, 9 H, Si(CH_3)$_3$], 0.07, 0.08 [2s, 6 H, Si(CH_3)$_2$], 0.76 (s, 6 H, 2 CH_3), 0.80 [d, ^3J = 6.8 Hz, 6 H, CH(C*H*$_3$)$_2$], 0.92 [t, ^3J = 8.4 Hz, 2 H, $OCH_2CH_2Si(CH_3)_3$], 1.20 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH_3), 1.25 (d, $^3J_{\alpha,\beta}$ = 6.9 Hz, 3 H, Ala-β-CH_3), 1.30 [s, 3 H, C(CH_3)$_2$], 1.31 (m, 2 H, DAP-4-CH_2), 1.36 [s, 9 H, C(CH_3)$_3$], 1.45 [s, 3 H, C(CH_3)$_2$], 1.52−1.62 [2m, 5 H, DAP-3-CH_2, DAP-5-CH_2, C*H*(CH_3)$_2$], 1.75 (s, 3 H, NH*Ac*), 1.76, 1.93 (2m, 2 H, Glu-β-CH_2), 2.16 (t, $^3J_{\beta,\gamma}$ = 7.5 Hz, 2 H, Glu-γ-CH_2), 3.19 (m, 1 H, 5-H), 3.42 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 9.3 Hz, 1 H, 3-H), 3.59, 3.61 (2s, 6 H, 2 OCH_3), 3.59−3.66 (m, 2 H, 2-H, 4-H), 3.71−3.80 (m, 2 H, 6-H, 6′-H), 3.91 (m, 1 H, DAP-6-H), 3.98 (q, $^3J_{\alpha,\beta}$ = 6.7 Hz, 1 H, Lac-α-H), 4.08−4.14 [m, 3 H, DAP-2-H, $OCH_2CH_2Si(CH_3)_3$], 4.21 (m, 1 H, Glu-α-H), 4.33 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.2 Hz, 1 H, Ala-α-H), 4.62 (d, $^3J_{1,2}$ = 7.8 Hz, 1 H, 1-H), 7.17 (d, $^3J_{\alpha,NH}$ = 7.7 Hz, 1 H, Boc-NH), 7.22 (d, $^3J_{\alpha,NH}$ = 7.8 Hz, 1 H, Ala-NH), 7.79 (d, $^3J_{2,NH}$ = 9.3 Hz, 1 H, N*H*Ac), 8.15 (d, $^3J_{\alpha,NH}$ = 7.1 Hz, 1 H, DAP-2-NH), 8.36 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D_6]DMSO): δ = −3.5, −2.0 [2C, Si(CH_3)$_2$], −1.6 [3C, Si(CH_3)$_3$], 16.7 [1C, $OCH_2CH_2Si(CH_3)_3$], 18.3, 18.4, 18.9, 18.9, 19.0, 19.6, 19.7 [7C, C*C*H_3, Ala-β-C, Lac-β-C, C(*C*H_3)$_2$CH(*C*H_3)$_2$], 21.9 (1C, DAP-4-C), 23.0 [1C, NHC(O)*C*H_3], 24.2 [1C, *C*(CH_3)$_2$CH(CH_3)$_2$], 26.9 (1C, Glu-β-C), 28.1 [3C, C(*C*H_3)$_3$], 28.9 (1C, C*C*H_3), 30.2, 30.3 (2C, DAP-3-C, DAP-5-C), 31.1 (1C, Glu-γ-C), 33.4 [1C, C(CH_3)$_2$*C*H(CH_3)$_2$], 47.5 (1C, Ala-α-C), 51.5, 51.6, 51.8 (4C, Glu-α-C, DAP-2-C, 2 OCH_3), 53.2 (1C, DAP-6-C), 56.5 (1C, 2-C), 61.4 (1C, 6-C), 62.4 [1C, O*C*$H_2CH_2Si(CH_3)_3$], 66.6 (1C, 5-C), 73.4 (1C, 4-C), 77.1 (1C, Lac-α-C), 78.1 [1C, *C*(CH_3)$_3$], 79.5 (1C, 3-C), 96.4 (1C, 1-C), 98.8 (1C, *C*CH_3), 155.4 (1C, 2 OC(O)NH), 169.1 [1C, NH*C*(O)CH_3], 171.2, 171.5 [2C, 2 C(O)NH], 172.0 [3C, 2 *C*O_2CH_3, *C*$O_2(CH_2)_2Si(CH_3)_3$], 172.9 [1C, C(O)NH] ppm. FAB MS (positive mode, NBA,

glycerol): *m/z* = 1098 $[M + Na]^+$. $C_{49}H_{89}N_5O_{17}Si_2$ (1076.4): calcd. C 54.67, H 8.33, N 6.51; found C 54.69, H 8.15, N 6.04.

Diammonium *N*-Acetyl-muramyl-L-alanyl-D-isoglutamyl-(2*S*,6*R*)-2,6-diaminopimelate (45): A solution of **44** (30 mg, 28 μmol) in dioxane/MeOH (15 mL) was saponified with 1 M LiOH according to Procedure D. The residue was treated with a TFA/dioxane/H_2O mixture (10 mL) according to Procedure E to remove the remaining protecting groups. After completion of the reaction (as determined by NMR spectroscopy) and removal of the solvent, the crude product was purified by gel chromatography (t_R = 45.5 min). The fractions containing the product (as judged by MALDI) were concentrated to a volume of 3−4 mL and lyophilized several times from H_2O to afford **45** (16 mg, 23 μmol, 83%) as a colorless lyophilizate. TLC (RP18): R_f = 0.17 (MeCN/H_2O = 4:1). $[\alpha]_D$ = +6.6 (*c* = 0.5, H_2O). ^1H NMR (600 MHz, [D$_6$]DMSO + TFA): δ (α anomer) = 1.22 (d, $^3J_{\alpha,\beta}$ = 6.8 Hz, 3 H, Ala-β-CH_3), 1.24 (d, $^3J_{\alpha,\beta}$ = 6.6 Hz, 3 H, Lac-β-CH_3), 1.38−1.42 (m, 2 H, DAP-4-CH_2), 1.54−1.56 (m, 1 H, DAP-3-CH_2), 1.71−1.76 (m, 4 H, DAP-3-CH_2, DAP-5-CH_2, Glu-β-CH_2), 1.78 (s, 3 H, NH*Ac*), 1.93−1.96 (m, 1 H, Glu-β-CH_2), 2.15−2.21 (m, 2 H, Glu-γ-CH_2), 3.25 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.0 Hz, 1 H, 4-H), 3.45 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 9.1 Hz, 1 H, 3-H), 3.50 (dd, $^3J_{5,6}$ = 5.7, $^2J_{6,6'}$ = 11.7 Hz, 1 H, 6-H), 3.61 (m, 2 H, 5-H, 6′-H), 3.68 (m, 1 H, 2-H), 3.88 (m, 1 H, DAP-6-H), 4.12−4.21 (m, 2 H, Glu-α-H, DAP-2-H), 4.27 (q, $^3J_{\alpha,\beta}$ = 6.7 Hz, 1 H, Lac-α-H), 4.34−4.38 (m, 1 H, Ala-α-H), 4.95 (d, $^3J_{1,2}$ = 3.4 Hz, 1 H, 1-H), 7.55 (d, $^3J_{\alpha,NH}$ = 8.0 Hz, 1 H, Ala-NH), 8.02 (d, $^3J_{2,NH}$ = 8.1 Hz, 1 H, N*H*Ac), 8.10 (d, $^3J_{\alpha,NH}$ = 7.9 Hz, 1 H, DAP-2-NH), 8.18 (br. d, $^3J_{\alpha,NH}$ = 5.1 Hz, 1 H, DAP-6-NH_3^+), 8.27 (d, $^3J_{\alpha,NH}$ = 7.9 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO + TFA): δ = 19.4 (1C, Ala-β-C), 19.5 (1C, Lac-β-C), 21.5 (1C, DAP-4-C), 23.1 [1C, NHC(O)*C*H$_3$], 27.7 (1C, Glu-β-C), 30.0 (1C, DAP-5-C), 30.9 (1C, DAP-3-C), 31.9 (1C, Glu-γ-C), 48.0 (1C, Ala-α-C), 52.0 (2C, Glu-α-C, DAP-2-C), 52.2 (1C, DAP-6-C), 54.1 (1C, 2-C) 61.3 (1C, 6-C), 70.4 (1C, 4-C), 72.7 (1C, 5-C), 76.7 (1C, Lac-α-C), 79.2 (1C, 3-C), 91.0 (1C, 1-C), 169.9, 171.4, 171.9, 172.4, 172.9, 173.5, 173.9 [7C, NH*C*(O)CH$_3$, 3 C(O)NH, 3 CO_2H] ppm. FAB MS (positive mode, glycerol, DMSO): *m/z* = 666 $[M - 2NH_4^+ + 3H^+]^+$; calcd. 699.7 for $C_{26}H_{49}N_7O_{15}$.

Thexyldimethylsilyl 2-Acetamido-2-deoxy-4,6-*O*-isopropylidene-3-*O*-(2*R*)-propionyl-[L-alanyl-(D-isoglutamyl α-methyl ester)-(7-methyl)-1-(2-trimethylsilylethyl)-{(2*S*,6*R*)-*N*^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelyl)-(D-alanine methyl ester)]-2-yl}-β-D-glucopyranoside (46): The tripeptide **35** (150 mg, 0.23 mmol) was hydrogenated (Procedure A) and coupled with compound **18** (130 mg, 0.23 mmol) according to Procedure B. Purification of the crude product by flash chromatography (SiO_2, toluene/ethanol/acetone = 8:2:1) and MPLC (25 × 1.6 cm, toluene/acetone = 1:1.1) afforded **46** (219 mg, 0.21 mmol, 90%) as a light yellow solid. TLC (SiO_2): R_f = 0.40 (toluene/acetone = 1:1). $[\alpha]_D$ = +4.9 (*c* = 1, MeOH). ^1H NMR (600 MHz, [D$_6$]DMSO): δ = 0.07, 0.08 [2s, 6 H, Si(CH$_3$)$_2$], 0.76 (s, 6 H, 2 CH$_3$), 0.80 [d, ^3J = 6.8 Hz, 6 H, CH(C*H*$_3$)$_2$], 1.20 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH_3), 1.20−1.27 (m, 8 H, Ala-β-CH_3, D-Ala-β-CH_3, DAP-4-CH_2), 1.30 [s, 3 H, C(CH$_3$)$_2$], 1.36 [s, 9 H, C(CH$_3$)$_3$], 1.45 [s, 3 H, C(CH$_3$)$_2$], 1.52−1.59 [m, 5 H, DAP-3-CH_2, DAP-5-CH_2, C*H*(CH$_3$)$_2$], 1.75 (s, 3 H, NH*Ac*), 1.74−1.78, 1.92−1.95 (2m, 2 H, Glu-β-CH_2), 2.16 (m, 2 H, Glu-γ-CH_2), 3.19 (m, 1 H, 5-H), 3.42 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 9.4 Hz, 1 H, 3-H), 3.58−3.68 (m, 2 H, 2-H, 4-H), 3.60, 3.61 (2s, 6 H, 2 OCH_3), 3.72 (t, $^2J_{6,6'}$ = 10.5, $^3J_{5,6}$ = 10.2 Hz, 1 H, 6-H), 3.76 (dd, $^2J_{6,6'}$ = 10.5, $^3J_{5,6'}$ = 5.5 Hz, 1 H, 6′-H), 3.87 (m, 1 H, DAP-6-H), 3.98 (q, $^3J_{\alpha,\beta}$ = 6.7 Hz, 1 H, Lac-α-H), 4.21 (m, 1 H, Glu-α-H), 4.24−4.27 (m, 2 H, DAP-2-H, D-Ala-α-H), 4.32 (m, 1 H, Ala-α-H), 4.62 (d, $^3J_{1,2}$ = 7.9 Hz, 1 H, 1-H), 7.15 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Boc-NH), 7.21 (d, $^3J_{\alpha,NH}$ = 7.8 Hz, 1 H, Ala-NH), 7.80 (d, $^3J_{2,NH}$ = 9.3 Hz, 1 H, N*H*Ac), 7.89 (d, $^3J_{\alpha,NH}$ = 8.1 Hz, 1 H, DAP-2-NH), 8.31 (d, $^3J_{\alpha,NH}$ = 7.1 Hz, 1 H, D-Ala-NH), 8.38 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −3.5, −2.0 [2C, Si(CH$_3$)$_2$], 17.0, 18.3, 18.4, 18.8, 18.9, 19.0, 19.7, 19.8 [8C, D-Ala-β-C, Ala-β-C, Lac-β-C, C*C*H$_3$, C(*C*H$_3$)$_2$CH(*C*H$_3$)$_2$], 21.7 (1C, DAP-4-C), 23.0 [1C, NHC(O)*C*H$_3$], 24.2 [1C, *C*(CH$_3$)$_2$CH(CH$_3$)$_2$], 27.1 (1C, Glu-β-C), 28.1 [3C, C(*C*H$_3$)$_3$], 28.9 (1C, C*C*H$_3$), 30.3, 31.9 (2C, DAP-3-C, DAP-5-C), 31.2 (1C, Glu-γ-C), 33.4 [1C, C(CH$_3$)$_2$*C*H(CH$_3$)$_2$], 47.4 (1C, D-Ala-α-C), 47.6 (1C, Ala-α-C), 51.5, 51.6, 51.8 (5C, Glu-α-C, DAP-2-C, 3 OCH_3), 53.5 (1C, DAP-6-C), 56.5 (1C, 2-C), 61.4 (1C, 6-C), 66.6 (1C, 5-C), 73.4 (1C, 4-C), 77.1 (1C, Lac-α-C), 78.1 [1C, *C*(CH$_3$)$_3$], 79.5 (1C, 3-C), 96.4 (1C, 1-C), 98.8 (1C, *C*CH$_3$), 155.6 [1C, OC(O)NH], 169.2 [1C, NH*C*(O)CH$_3$], 170.9, 171.4 [2C, 2 C(O)NH], 172.1 (3C, 3 *C*O$_2$CH$_3$), 172.8, 173.1 [2C, 2 C(O)NH] ppm. FAB MS (positive mode, NBA, glycerol): *m/z* = 1083 $[M + Na]^+$. $C_{48}H_{84}N_6O_{18}Si{\cdot}H_2O$ (1079.3): calcd. C 53.41, H 8.03, N 7.79; found C 53.72, H 7.91, N 7.59.

Diammonium *N*-Acetylmuramyl-L-alanyl-D-isoglutamyl-(2*S*,6*S*)-2,6-diaminopimelyl-D-alanine (47): A solution of **46** (60 mg, 57 μmol) in dioxane/MeOH (16 mL) was saponified with 1 M LiOH (Procedure D). The residue was treated with TFA/dioxane/H_2O (15 mL) according to Procedure E. Purification of the crude product by gel chromatography (t_R = 41.2 min) afforded **47** (33 mg, 43 μmol, 76%) as a colorless lyophilizate (from water). TLC (RP-18): R_f = 0.21 (MeCN/H_2O = 4:1). $[\alpha]_D$ = +2.6 (*c* = 0.5, H_2O). ^1H NMR (600 MHz, [D$_6$]DMSO + TFA): δ (α anomer) = 1.99−1.25 (m, 9 H, Lac-β-CH_3, Ala-β-CH_3, D-Ala-β-CH_3), 1.36 (m, 2 H, DAP-4-CH_2), 1.49, 1.63 (2m, 2 H, DAP-3-CH_2), 1.69−1.82 (m, 3 H, DAP-5-CH_2, Glu-β-CH_2), 1.78 (s, 3 H, NH*Ac*), 1.98 (m, 1 H, Glu-β-CH_2), 2.17 (m, 2 H, Glu-γ-CH_2), 3.25 (t, $^3J_{3,4} \approx {}^3J_{4,5}$ = 9.1 Hz, 1 H, 4-H), 3.45 (t, $^3J_{2,3} \approx {}^3J_{3,4}$ = 9.1 Hz, 1 H, 3-H), 3.51 (dd, $^3J_{5,6}$ = 5.2, $^2J_{6,6'}$ = 11.9 Hz, 1 H, 6-H), 3.61 (m, 2 H, 5-H, 6′-H), 3.69 (m, 1 H, 2-H), 3.84 (m, 1 H, DAP-6-H), 4.17−4.22 (m, 2 H, Ala-α-H, Glu-α-H), 4.26−4.29 (m, 2 H, Lac-α-H, DAP-2-H), 4.32−4.38 (m, 1 H, D-Ala-α-H), 4.96 (d, $^3J_{1,2}$ = 3.0 Hz, 1 H, 1-H), 7.56 (d, $^3J_{\alpha,NH}$ = 7.8 Hz, 1 H, D-Ala-NH), 7.94 (d, $^3J_{\alpha,NH}$ = 8.1 Hz, 1 H, DAP-2-NH), 8.04 (d, $^3J_{2,NH}$ = 8.0 Hz, 1 H, N*H*Ac), 8.13 (d, $^3J_{\alpha,NH}$ = 7.2 Hz, 1 H, Ala-NH), 8.18 (br. s, 3 H, DAP-6-NH_3^+), 8.26 (d, $^3J_{\alpha,NH}$ = 7.8 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO + TFA): δ = 17.4, 19.08, 19.14 (3C, Lac-β-C, Ala-β-C, D-Ala-β-C), 20.9 (1C, DAP-4-C), 21.1 [1C, NHC(O)*C*H$_3$], 27.5 (1C, Glu-β-C), 29.8 (1C, DAP-5-C), 31.7 (1C, Glu-γ-C), 31.9 (1C, DAP-3-C), 47.6 (1C, Ala-α-C), 47.8 (1C, D-Ala-α-C), 51.7 (1C, Glu-α-C), 52.0 (2C, DAP-2-C, DAP-6-C), 53.8 (1C, 2-C), 61.0 (1C, 6-C), 70.0 (1C, 4-C), 72.4 (1C, 5-C), 76.6 (1C, Lac-α-C), 79.1 (1C, 3-C), 90.7 (1C, 1-C), 169.7, 171.2, 171.4, 171.5, 172.2, 172.3, 172.7, 173.3, 174.1 [8C, NH*C*(O)CH$_3$, 4 C(O)NH, 3 CO_2H] ppm. FAB MS (positive mode, glycerol, MeCN/0.1% TFA = 1:1): *m/z* = 737 $[M - 2NH_4^+ + 3H^+]^+$, 759 $[M - 2NH_4^+ + 2H^+ + Na^+]^+$, 775 $[M - 2NH_4^+ + 2H^+ + K^+]^+$, 869 $[M - 2NH_4^+ + 2H^+ + Cs^+]^+$; calcd. 770.8 for $C_{29}H_{54}N_8O_{16}$.

1,6-Anhydro-2-azido-4-*O*-benzyl-2-deoxy-3-*O*-{(2*R*)-propionyl-[L-alanyl-(D-isoglutamyl α-methyl ester)-(7-methyl)-1-(2-trimethylsilylethyl) (2*S*,6*R*)-*N*^{ε}-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate]-2-yl}-β-D-glucopyranose (48a): The tripeptide **32a** (245 mg, 0.33 mmol) was hydrogenated (Procedure A) and coupled with compound **26** (137 mg, 0.39 mmol) according to Procedure C. Purification of the crude product by flash chromatography (SiO_2, toluene/acetone = 3:2) afforded **48a** (277 mg, 0.29 mmol, 89%) as a

colorless foam. TLC (SiO_2): R_f = 0.47 (toluene/acetone = 3:2). $[\alpha]_D$ = +15.9 (c = 1, MeOH). ^1H NMR (600 MHz, [D$_6$]DMSO): δ = 0.01 [s, 9 H, Si(CH$_3$)$_3$], 0.92 [t, ^3J = 8.4 Hz, 2 H, OCH$_2$CH_2Si(CH$_3$)$_3$], 1.21 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH$_3$), 1.23 (d, $^3J_{\alpha,\beta}$ = 7.0 Hz, 3 H, Ala-β-CH$_3$), 1.32−1.35 (m, 2 H, DAP-4-CH$_2$), 1.36 [s, 9 H, C(CH$_3$)$_3$], 1.48−1.57, 1.59−1.65 (2m, 4 H, DAP-3-CH$_2$, DAP-5-CH$_2$), 1.72−1.82, 1.89−1.95 (2m, 2 H, Glu-β-CH$_2$), 2.16 (t, $^3J_{\beta,\gamma}$ = 7.7 Hz, 2 H, Glu-γ-CH$_2$), 3.34 (s, 1 H, 2-H), 3.47 (s, 1 H, 4-H), 3.56 (s, 1 H, 3-H), 3.60, 3.61 (2s, 6 H, 2 OCH$_3$), 3.62−3.63 (m, 1 H, 6-H), 3.88−3.95 (m, 1 H, DAP-6-H), 4.00−4.03 (m, 2 H, Lac-α-H, 6′-H), 4.08−4.11 [m, 3 H, OCH_2CH$_2$Si(CH$_3$)$_3$, DAP-2-H], 4.24 (m, 1 H, Glu-α-H), 4.38 (m, 1 H, Ala-α-H), 4.64 (m, 2 H, CH_2Ph), 4.76 (d, $^3J_{5,6}$ = 5.3 Hz, 1 H, 5-H), 5.54 (s, 1 H, 1-H), 7.17 (d, $^3J_{\alpha,NH}$ = 7.7 Hz, 1 H, Boc-NH), 7.24−7.38 (m, 5 H, Ph), 7.73 (d, $^3J_{\alpha,NH}$ = 8.0 Hz, 1 H, Ala-NH), 8.16 (d, $^3J_{\alpha,NH}$ = 7.4 Hz, 1 H, DAP-2-NH), 8.34 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −1.5 [3C, Si(CH$_3$)$_3$], 16.7 [1C, OCH$_2$CH_2Si(CH$_3$)$_3$], 18.2 (1C, Lac-β-C), 18.9 (1C, Ala-β-C), 21.9 (1C, DAP-4-C), 27.0 (1C, Glu-β-C), 28.1 [3C, CCH$_3$)$_3$], 30.2, 30.3 (2C, DAP-3-C, DAP-5-C), 31.0 (1C, Glu-γ-C), 47.5 (1C, Ala-α-C), 51.5 (1C, Glu-α-C), 51.6 (2C, 2 OCH$_3$), 51.8 (1C, DAP-2-C), 53.2 (1C, DAP-6-C), 58.3 (1C, 2-C), 62.4 [1C, OCH$_2$CH$_2$Si(CH$_3$)$_3$], 64.8 (1C, 6-C), 70.3 (1C, CH$_2$Ph), 73.4 (1C, 5-c), 75.1, 75.1 (2C, Lac-α-C, 4-C), 75.4 (1C, 3-C), 78.1 [1C, C(CH$_3$)$_3$], 99.5 (1C, 1-C), 128.2, 127.6, 127.5, 137.9 (6C, Ph), 155.5 [1C, OC(O)NH], 171.1, 171.2, 172.0, 173.0 [6C, 2 CO$_2$CH$_3$, 3 C(O)NH, CO$_2$(CH$_2$)$_2$Si(CH$_3$)$_3$] ppm. $C_{43}H_{67}N_7O_{15}Si$ (950.1): calcd. C 54.36, H 7.11, N 10.32; found C 54.38, H 6.81, N 10.36.

2-Acetamido-1,6-anhydro-2-deoxy-3-*O*-{(2*R*)-propionyl-[L-alanyl-(D-isoglutamyl α-methyl ester)-(7-methyl)-1-(2-trimethylsilylethyl) (2*S*,6*R*)-*N*$^{\varepsilon}$-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate]-2-yl}-β-D-glucopyranose (49a): Pd/C (32 mg) and Ac_2O (52 mg, 0.51 mmol) were added to a solution of azide **48a** (320 mg, 0.34 mmol) in MeOH (32 mL). The reaction mixture was hydrogenated according to Procedure A. After completion (as judged by TLC), the solution was filtered through Celite and evaporated, and the residue was purified by flash chromatography over a short column (SiO_2, acetone). The pure acetamide **49a** (286 mg, 0.33 mmol, 97%) was afforded as a colorless lyophilizate (from dioxane). TLC (SiO_2): R_f = 0.49 (toluene/acetone = 1:3). $[\alpha]_D$ = −17.3 (c = 1, MeOH). ^1H NMR (600 MHz, [D$_6$]DMSO): δ = 0.01 [s, 9 H, Si(CH$_3$)$_3$], 0.92 [t, ^3J = 8.4 Hz, 2 H, OCH$_2$CH_2Si(CH$_3$)$_3$], 1.22 (d, $^3J_{\alpha,\beta}$ = 7.1 Hz, 3 H, Lac-β-CH$_3$), 1.24 (d, $^3J_{\alpha,\beta}$ = 7.4 Hz, 3 H, Ala-β-CH$_3$), 1.31 (m, 2 H, DAP-4-CH$_2$), 1.36 [s, 9 H, C(CH$_3$)$_3$], 1.52−1.54, 1.61−1.62 (2m, 4 H, DAP-3-CH$_2$, DAP-5-CH$_2$), 1.76 (m, 1 H, Glu-β-CH$_2$), 1.84 (s, 3 H, NHAc), 1.93 (m, 1 H, Glu-β-CH$_2$), 2.16 (t, $^3J_{\beta,\gamma}$ = 7.6 Hz, 2 H, Glu-γ-CH$_2$), 3.23 (s, 1 H, 3-H), 3.51 (d, $^3J_{4,OH}$ = 5.0 Hz, 1 H, 4-H), 3.60, 3.62 (2s, 6 H, 2 OCH$_3$), 3.60−3.62 (m, 1 H, 6-H), 3.65 (d, $^3J_{2,NH}$ = 8.5 Hz, 1 H, 2-H), 3.90 (m, 1 H, DAP-6-H), 4.05 (d, J = 7.4 Hz, 1 H, 6′-H), 4.07−4.13 [m, 4 H, Lac-α-H, OCH_2CH$_2$Si(CH$_3$)$_3$, DAP-2-H], 4.23 (m, 1 H, Glu-α-H), 4.37 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.5 Hz, 1 H, Ala-α-H), 4.48 (d, $^3J_{5,6}$ = 5.2 Hz, 1 H, 5-H), 5.27 (s, 1 H, 1-H), 5.29 (d, $^3J_{4,OH}$ = 5.8 Hz, 1 H, 4-OH), 7.20 (d, $^3J_{\alpha,NH}$ = 7.8 Hz, 1 H, Boc-NH), 7.70 (d, $^3J_{\alpha,NH}$ = 8.3 Hz, 1 H, Ala-NH), 7.73 (d, $^3J_{2,NH}$ = 8.6 Hz, 1 H, NHAc), 8.19 (d, $^3J_{\alpha,NH}$ = 7.3 Hz, 1 H, DAP-2-NH), 8.39 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −1.5 [3C, Si(CH$_3$)$_3$], 16.7 [1C, OCH$_2$CH_2Si(CH$_3$)$_3$], 17.8 (1C, Lac-β-C), 19.1 (1C, Ala-β-C), 21.9 (1C, DAP-4-C), 22.5 [1C, NHC(O)CH_3], 27.0 (1C, Glu-β-C), 28.1 [3C, C(CH_3)$_3$], 30.2, 30.3 (2C, DAP-3-C, DAP-5-C), 31.1 (1C, Glu-γ-C), 47.4 (1C, Ala-α-C), 48.8 (1C, 2-C), 51.5 (1C, Glu-α-C), 51.7 (2C, 2 OCH$_3$), 51.9 (1C, DAP-2-C), 53.2 (1C, DAP-6-C), 62.5 [1C, OCH$_2$CH$_2$Si(CH$_3$)$_3$], 64.8 (1C, 6-C), 69.1 (1C, 4-C), 74.4 (1C, Lac-α-C), 75.9 (1C, 5-C), 78.2 [1C, C(CH$_3$)$_3$], 79.1 (1C, 3-C), 100.1 (1C, 1-C), 155.5 [1C, OC(O)NH], 169.2 [1C, NHC(O)CH$_3$], 171.3, 172.2, 172.2, 173.0 [6C, 2 CO$_2$CH$_3$, 3 C(O)NH, CO$_2$(CH$_2$)$_2$Si(CH$_3$)$_3$] ppm. $C_{38}H_{65}N_5O_{16}Si$ (876.0): calcd. C 52.10, H 7.48, N 7.99; found C 52.20, H 7.91, N 7.51.

Diammonium (*N*-Acetyl-1,6-anhydro-muramyl)-L-alanyl-*N*$^{\alpha}$-(D-isoglutamyl)-(2*S*,6*R*)-2,6-diaminopimelate (50a). (a) Synthesis: A solution of compound **49a** (80 mg, 91 μmol) in 50% TFA/CH_2Cl_2 (16 mL) was stirred for 3−4 h in order to remove the Boc and TMSE groups. When reaction was complete (as judged by NMR spectroscopy), the solution was concentrated at low temperature (25 °C) to a volume of 0.5 mL. Remaining TFA was removed by coevaporation with dry toluene (5 × 5 mL), and the residue was then dissolved in H_2O/MeOH (2:1, v/v, 21 mL) for saponification with 1 M LiOH according to Procedure D. After completion of the reaction (as judged by NMR spectroscopy, 4 days), glacial AcOH was used to neutralize the solution and the solvent was removed at low temperature.

(b) Purification: The crude product was purified by ion-exchange chromatography (Dowex 50 W X2) on resin that had been washed successively with MeOH, 25% aqueous NH_3, H_2O, 1 M aqueous HCl, and H_2O until neutral. The acidified crude product was applied to the column, then washed with H_2O until the eluent was neutral. Aqueous NH_3 (1% of a 25% NH_3 solution in H_2O) was used to elute the product, which was detected by TLC (ninhydrin). The eluent was concentrated to 1−2 mL, lyophilized, and applied to a reversed-phase column (RP-18, MeCN/H_2O = 6:1) to afford **50a** (53 mg, 78 μmol, 86%) as a colorless lyophilizate. TLC (RP-18): R_f = 0.23 (MeCN/H_2O = 5:1). $[\alpha]_D$ = −14.4 (c = 0.5, H_2O). ^1H NMR (600 MHz, [D$_6$]DMSO + TFA): δ = 1.22 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH$_3$), 1.23 (d, $^3J_{\alpha,\beta}$ = 6.9 Hz, 3 H, Ala-β-CH$_3$), 1.36−1.42 (m, 2 H, DAP-4-CH$_2$), 1.53−1.56 (m, 1 H, DAP-3-CH$_2$), 1.68−1.76 (m, 2 H, DAP-3-CH$_2$, DAP-5-CH$_2$, Glu-β-CH$_2$), 1.84 (s, 3 H, NHAc), 1.93−1.97 (m, 1 H, Glu-β-CH$_2$), 2.14−2.18 (m, 2 H, Glu-γ-CH$_2$), 3.23 (s, 1 H, 3-H), 3.51 (s, 1 H, 4-H), 3.61 (t, $^3J_{5,6}$ = 5.9, $^2J_{6,6'}$ = 7.3 Hz, 1 H, 6-H), 3.65 (d, $^3J_{2,NH}$ = 8.7 Hz, 1 H, 2-H), 3.87 (m, 1 H, DAP-6-H), 4.05−4.09 (m, 2 H, 6′-H, Lac-α-H), 4.13 (dt, ^3J = 4.9, $^3J_{\alpha,NH}$ = 8.5 Hz, 1 H, DAP-2-H), 4.18 (dt, ^3J = 5.2, $^3J_{\alpha,NH}$ = 8.4 Hz, 1 H, Glu-α-H), 4.38 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Ala-α-H), 4.48 (d, $^3J_{5,6}$ = 5.8 Hz, 1 H, 5-H), 5.27 (s, 1 H, 1-H), 7.71 (d, $^3J_{\alpha,NH}$ = 8.3 Hz, 1 H, Ala-NH), 7.74 (d, $^3J_{2,NH}$ = 8.6 Hz, 1 H, NHAc), 8.13 (d, $^3J_{\alpha,NH}$ = 7.9 Hz, 1 H, DAP-2-NH), 8.20 (bd, $^3J_{\alpha,NH}$ = 5.2 Hz, 3 H, DAP-6-NH$_3^+$), 8.28 (d, $^3J_{\alpha,NH}$ = 7.9 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO + TFA): δ = 17.9 (1C, Lac-β-C), 19.2 (1C, Ala-β-C), 21.2 (1C, DAP-4-C), 22.5 [1C, NHC(O)CH_3], 27.3 (1C, Glu-β-C), 29.7 (1C, DAP-5-C), 30.6 (1C, DAP-3-C), 31.5 (1C, Glu-γ-C), 47.5 (1C, Ala-α-C), 48.8 (1C, 2-C), 51.6 (1C, Glu-α-C), 51.7 (1C, DAP-2-C), 51.8 (1C, DAP-6-C), 64.9 (1C, 6-C), 69.2 (1C, 4-C), 74.5 (1C, Lac-α-C), 76.0 (1C, 5-C), 79.2 (1C, 3-C), 100.2 (1C, 1-C), 169.3 [1C, NHC(O)CH$_3$], 171.1, 171.4, 171.6, 172.1, 173.2, 173.6 [6C, 3 CO$_2$H, 3 C(O)NH] ppm. FAB MS (positive mode, glycerol, MeOH/AcOH/H_2O = 1:1:1): m/z = 648 [M − 2NH$_4^+$ + 3H$^+$]$^+$; calcd. 681.3 for $C_{26}H_{47}N_7O_{14}$.

1,6-Anhydro-2-azido-4-*O*-benzyl-2-deoxy-3-*O*-{(2*R*)-propionyl-[L-alanyl-(D-isoglutamyl α-methyl ester)-(7-methyl)-1-(2-trimethylsilylethyl) (2*S*,6*S*)-*N*$^{\varepsilon}$-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate}]-2-yl}-β-D-glucopyranose (48b): The tripeptide **32b** (400 mg, 0.54 mmol) was hydrogenated (Procedure A) and coupled with compound **26** (225 mg, 0.64 mmol) according to Procedure C. The reaction was complete after 10 h, as determined by TLC. Purification of the crude product by flash chromatography (SiO_2, toluene/

acetone = 3:2) afforded **48b** (423 mg, 0.45 mmol, 83%) as a colorless foam. TLC (SiO_2): R_f = 0.47 (toluene/acetone = 3:2). $[\alpha]_D$ = +9.1 (*c* = 1.1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 0.01 [s, 9 H, Si(CH$_3$)$_3$], 0.92 [t, ^3J = 8.5 Hz, 2 H, OCH$_2$C*H*$_2$Si(CH$_3$)$_3$], 1.21 (d, $^3J_{\alpha,\beta}$ = 6.7 Hz, 3 H, Lac-β-CH$_3$), 1.23 (d, $^3J_{\alpha,\beta}$ = 7.0 Hz, 3 H, Ala-β-CH$_3$), 1.31 (m, 2 H, DAP-4-CH$_2$), 1.36 [s, 9 H, C(CH$_3$)$_3$], 1.53−1.62 (m, 4 H, DAP-3-CH$_2$, DAP-5-CH$_2$), 1.76−1.79, 1.91−1.94 (2m, 2 H, Glu-β-CH$_2$), 2.16 (t, $^3J_{\beta,\gamma}$ = 7.8 Hz, 2 H, Glu-γ-CH$_2$), 3.36 (s, 1 H, 2-H), 3.46 (s, 1 H, 4-H), 3.56 (s, 1 H, 3-H), 3.59, 3.60 (2s, 6 H, 2 OCH$_3$), 3.63 (t, *J* = 7.1 Hz, 1 H, 6-H), 3.87−3.89 (m, 1 H, DAP-6-H), 4.00−4.03 (m, 2 H, Lac-α-H, 6′-H), 4.08−4.12 [m, 3 H, OC*H*$_2$CH$_2$Si(CH$_3$)$_3$, DAP-2-H], 4.24 (q, $^3J_{\alpha,\beta}$ = 5.6 Hz, 1 H, Glu-α-H), 4.37 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.4 Hz, 1 H, Ala-α-H), 4.64 (m, 2 H, C*H*$_2$Ph), 4.76 (d, $^3J_{5,6}$ = 5.4 Hz, 1 H, 5-H), 5.54 (s, 1 H, 1-H), 7.20 (d, $^3J_{\alpha,NH}$ = 7.7 Hz, 1 H, Boc-NH), 7.28−7.38 (m, 5 H, Ph), 7.74 (d, $^3J_{\alpha,NH}$ = 8.0 Hz, 1 H, Ala-NH), 8.18 (d, $^3J_{\alpha,NH}$ = 7.4 Hz, 1 H, DAP-2-NH), 8.36 (d, $^3J_{\alpha,NH}$ = 7.7 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −1.5 [3C, Si(CH$_3$)$_3$], 16.8 [1C, OCH$_2$*C*H$_2$Si(CH$_3$)$_3$], 18.2 (1C, Lac-β-C), 18.9 (1C, Ala-β-C), 22.1 (1C, DAP-4-C), 27.0 (1C, Glu-β-C), 28.1 [3C, C(*C*H$_3$)$_3$], 30.2, 30.4 (2C, DAP-3-C, DAP-5-C), 31.1 (1C, Glu-γ-C), 47.5 (1C, Ala-α-C), 51.5 (1C, Glu-α-C), 51.7, 51.9 (3C, 2 OCH$_3$, DAP-2-C), 53.4 (1C, DAP-6-C), 58.3 (1C, 2-C), 62.5 [1C, O*C*H$_2$CH$_2$Si(CH$_3$)$_3$], 64.8 (1C, 6-C), 70.3 (1C, *C*H$_2$Ph), 73.4 (1C, 5-C), 75.1, 75.4 (3C, Lac-α-C, 4-C, 3-C), 78.2 [1C, *C*(CH$_3$)$_3$], 99.5 (1C, 1-C), 127.5, 127.6, 128.2, 137.9 (6C, Ph), 155.5 [1C, OC(O)NH], 171.1, 171.3, 172.1, 172.1, 173.1 [6C, 2 *C*O$_2$CH$_3$, 3 C(O)NH, *C*O$_2$(CH$_2$)$_2$Si(CH$_3$)$_3$] ppm. $C_{43}H_{67}N_7O_{15}Si$ (950.1): calcd. C 54.36, H 7.11, N 10.32; found C 54.69, H 7.47, N 10.30.

2-Acetamido-1,6-anhydro-2-deoxy-3-*O*-{(2*R*)-propionyl-[L-alanyl-(D-isoglutamyl α-methyl ester)-(7-methyl)-1-(2-trimethylsilylethyl) (2*S*,6*S*)-*N*$^{\varepsilon}$-(*tert*-butyloxycarbonyl)-2,6-diaminopimelate]-2-yl}-β-D-glucopyranose (49b): Pd/C (28 mg) and Ac$_2$O (45 mg, 0.44 mmol) were added to a solution of azide **48b** (280 mg, 0.30 mmol) in MeOH (20 mL). The reaction mixture was hydrogenated according to Procedure A. After completion (as judged by TLC), the solution was filtered through Celite and evaporated, and the residue was purified by flash chromatography over a short column (SiO_2, toluene/acetone = 1:3). The pure acetamide **49b** (255 mg, 0.29 mmol, 98%) was obtained as a colorless lyophilizate (from dioxane). TLC (SiO_2): R_f = 0.53 (toluene/acetone = 1:3). $[\alpha]_D$ = −22.3 (*c* = 1, MeOH). ^{1}H NMR (600 MHz, [D$_6$]DMSO): δ = 0.01 [s, 9 H, Si(CH$_3$)$_3$], 0.92 [t, ^3J = 8.4 Hz, 2 H, OCH$_2$C*H*$_2$Si(CH$_3$)$_3$], 1.22 (d, $^3J_{\alpha,\beta}$ = 7.0 Hz, 3 H, Lac-β-CH$_3$), 1.23 (d, $^3J_{\alpha,\beta}$ = 7.1 Hz, 3 H, Ala-β-CH$_3$), 1.31 (m, 2 H, DAP-4-CH$_2$), 1.36 [s, 9 H, C(CH$_3$)$_3$], 1.55−1.60 (m, 4 H, DAP-3-CH$_2$, DAP-5-CH$_2$), 1.75−1.79 (m, 1 H, Glu-β-CH$_2$), 1.84 (s, 3 H, NH*Ac*), 1.91−1.95 (m, 1 H, Glu-β-CH$_2$), 2.16 (t, $^3J_{\beta,\gamma}$ = 7.7 Hz, 2 H, Glu-γ-CH$_2$), 3.23 (s, 1 H, 3-H), 3.51 (d, $^3J_{4,OH}$ = 5.1 Hz, 1 H, 4-H), 3.60, 3.62 (2s, 6 H, 2 OCH$_3$), 3.60−3.62 (m, 1 H, 6-H), 3.65 (d, $^3J_{2,NH}$ = 8.5 Hz, 1 H, 2-H), 3.88 (m, 1 H, DAP-6-H), 4.05 (d, *J* = 7.3 Hz, 1 H, 6′-H), 4.07−4.13 [m, 4 H, Lac-α-H, OC*H*$_2$CH$_2$Si(CH$_3$)$_3$, DAP-2-H], 4.23 (m, 1 H, Glu-α-H), 4.37 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.4 Hz, 1 H, Ala-α-H), 4.48 (d, $^3J_{5,6}$ = 5.1 Hz, 1 H, 5-H), 5.27 (s, 1 H, 1-H), 5.29 (d, $^3J_{4,OH}$ = 5.8 Hz, 1 H, 4-OH), 7.19 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Boc-NH), 7.70 (d, $^3J_{\alpha,NH}$ = 8.3 Hz, 1 H, Ala-NH), 7.73 (d, $^3J_{2,NH}$ = 8.6 Hz, 1 H, N*H*Ac), 8.18 (d, $^3J_{\alpha,NH}$ = 7.3 Hz, 1 H, DAP-2-NH), 8.39 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO): δ = −1.5 [3C, Si(CH$_3$)$_3$], 16.8 [1C, OCH$_2$*C*H$_2$Si(CH$_3$)$_3$], 17.8 (1C, Lac-β-C), 19.1 (1C, Ala-β-C), 22.1 (1C, DAP-4-C), 22.5 [1C, NHC(O)*C*H$_3$], 26.9 (1C, Glu-β-C), 28.1 [3C, C(*C*H$_3$)$_3$], 30.2, 30.4 (2C, DAP-3-C, DAP-5-C), 31.1 (1C, Glu-γ-C), 47.4 (1C, Ala-α-C), 48.8 (1C, 2-C), 51.5 (1C, Glu-α-C), 51.7, 51.9 (3C, 2 OCH$_3$, DAP-2-C), 53.4 (1C, DAP-6-C), 62.5 [1C, O*C*H$_2$CH$_2$Si(CH$_3$)$_3$], 64.8 (1C, 6-C), 69.1 (1C, 4-C), 74.4 (1C, Lac-α-C), 75.9 (1C, 5-C), 78.2 [1C, *C*(CH$_3$)$_3$], 79.1 (1C, 3-C), 100.1 (1C, 1-C), 155.5 [1C, OC(O)NH], 169.2 [1C, NH*C*(O)CH$_3$], 171.3, 172.1, 172.2 [6C, 2 *C*O$_2$CH$_3$, 3 C(O)NH, *C*O$_2$(CH$_2$)$_2$Si(CH$_3$)$_3$] ppm. $C_{38}H_{65}N_5O_{16}Si\cdot 0.5\ H_2O$ (884.4): calcd. C 51.61, H 7.41, N 7.92; found C 51.70, H 7.75, N 7.49.

Diammonium (*N*-Acetyl-1,6-anhydromuramyl)-L-alanyl-*N*$^{\alpha}$-(D-isoglutamyl)-(2*S*,6*S*)-2,6-diaminopimelate (50b): This reaction was performed as described for compound **50a**. A solution of compound **49b** (127 mg, 145 μmol) in 50% TFA/CH_2Cl_2 (20 mL) was stirred for 2 h in order to remove the Boc and TMSE groups. After removal of the solvent, the residue was saponified with LiOH in H_2O/MeOH (1 M, 2:1, v/v, 30 mL) and stirred for 4 days. The crude product was subsequently purified by ion-exchange chromatography (Dowex 50 W X2), reversed-phase chromatography (RP-18, MeCN/H_2O = 6:1), and again by ion-exchange chromatography (Dowex 50 W X2) as described above. The pure product **50b** (76 mg, 112 μmol, 77%) was obtained as a light yellow lyophilizate. TLC (RP-18): R_f = 0.24 (MeCN/H_2O = 5:1). $[\alpha]_D$ = −23.2 (*c* = 0.5, H_2O). ^{1}H NMR (600 MHz, [D$_6$]DMSO + TFA): δ = 1.22 (d, $^3J_{\alpha,\beta}$ = 7.1 Hz, 3 H, Lac-β-CH$_3$), 1.23 (d, $^3J_{\alpha,\beta}$ = 8.4 Hz, 3 H, Ala-β-CH$_3$), 1.35, 1.46 (2m, 2 H, DAP-4-CH$_2$), 1.56 (m, 1 H, DAP-3-CH$_2$), 1.67−1.79 (m, 4 H, DAP-3-CH$_2$, DAP-5-CH$_2$, Glu-β-CH$_2$), 1.84 (s, 3 H, NH*Ac*), 1.95−1.97 (m, 1 H, Glu-β-CH$_2$), 2.15−2.19 (m, 2 H, Glu-γ-CH$_2$), 3.23 (s, 1 H, 3-H), 3.51 (s, 1 H, 4-H), 3.60 (m, 1 H, 6-H), 3.67 (d, $^3J_{2,NH}$ = 8.4 Hz, 1 H, 2-H), 3.87 (m, 1 H, DAP-6-H), 4.06−4.09 (m, 2 H, 6′-H, Lac-α-H), 4.13 (dt, ^3J = 4.9, $^3J_{\alpha,NH}$ = 8.2 Hz, 1 H, DAP-2-H), 4.19 (dt, ^3J = 5.4, $^3J_{\alpha,NH}$ = 8.1 Hz, 1 H, Glu-α-H), 4.38 (dq, $^3J_{\alpha,\beta} \approx {}^3J_{\alpha,NH}$ = 7.4 Hz, 1 H, Ala-α-H), 4.47 (d, $^3J_{5,6}$ = 4.9 Hz, 1 H, 5-H), 5.27 (s, 1 H, 1-H), 7.72 (d, $^3J_{\alpha,NH}$ = 7.3 Hz, 1 H, Ala-NH), 7.73 (d, $^3J_{2,NH}$ = 7.9 Hz, 1 H, N*H*Ac), 8.11 (d, $^3J_{\alpha,NH}$ = 7.6 Hz, 1 H, DAP-2-NH), 8.19 (br. s, 3 H, DAP-6-NH$_3^+$), 8.26 (d, $^3J_{\alpha,NH}$ = 7.8 Hz, 1 H, Glu-NH) ppm. ^{13}C NMR (150.8 MHz, [D$_6$]DMSO + TFA): δ = 18.1 (1C, Lac-β-C), 19.3 (1C, Ala-β-C), 21.5 (1C, DAP-4-C), 22.6 [1C, NHC(O)*C*H$_3$], 27.5 (1C, Glu-β-C), 29.9 (1C, DAP-5-C), 30.8 (1C, DAP-3-C), 31.7 (1C, Glu-γ-C), 47.8 (1C, Ala-α-C), 49.1 (1C, 2-C), 51.9 (1C, Glu-α-C, DAP-2-C), 52.1 (1C, DAP-6-C), 65.1 (1C, 6-C), 69.4 (1C, 4-C), 74.8 (1C, Lac-α-C), 76.2 (1C, 5-C), 79.4 (1C, 3-C), 100.4 (1C, 1-C), 169.6 [1C, NH*C*(O)CH$_3$], 171.4, 171.8, 171.9, 172.3, 173.5, 173.9 [6C, 3 *C*O$_2$H, 3 C(O)NH] ppm. FAB MS (positive mode, glycerol, MeCN/0.1% TFA = 1:1): *m/z* = 648 [M − 2NH$_4^+$ + 3H$^+$]$^+$; calcd. 681.3 for $C_{26}H_{47}N_7O_{14}$.

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