From Disulfide- to Thioether-linked Glycoproteins

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**Scheme S1.** $\delta$-attack followed by thio-mitsunobu mechanism.

**Scheme S2.** $\gamma$-attack followed by thio-mitsunobu mechanism.

**Scheme S3.** $\gamma$-attack followed by elimination-conjugate addition mechanism.
General procedures

Melting points were recorded on a Kofler hot block and are uncorrected. Proton nuclear magnetic resonance (**δ**^1^H) spectra were recorded on a Bruker AV400 (400 MHz), or by Dr. B. Odell or Dr. T. Claridge on a Bruker AVII500 (500 MHz) spectrometer. Carbon nuclear magnetic resonance (**δ**^1^C) spectra were recorded on a Bruker AV400 (100.7 MHz) spectrometer or by Dr. B. Odell or Dr. T. Claridge on a Bruker AVII500 (125.8 MHz) spectrometer. Spectra were fully assigned using COSY and HMQC; multiplicities were assigned using DEPT 135. All chemical shifts are quoted on the δ scale in ppm using residual solvent as the internal standard (1H NMR: CDCl₃ = 7.26, CD₃OD = 4.87; ^1^3^C^ NMR: CDCl₃ = 77.0; CD₃OD = 49.0; D₂O = 4.80). The following splitting abbreviations were used: s = singlet, d = doublet, t = triplet, q = quartet, a = apparent.

Infrared spectra were recorded on a Bruker Tensor 27 Fourier Transform spectrophotometer using thin films on NaCl plates for oils and KBr discs for solids and crystals. Absorption maxima (**υ**^max^) are reported in wavenumbers (cm⁻¹) and classified as strong (s) or broad (br). Only signals representing functional groups are reported; C-H absorptions as well as the fingerprint region are not listed.

Low resolution mass spectra were recorded on a Micromass Platform 1 spectrometer using electrospray ionization (ESI) or by Mr. Robin Proctor using a Walters 2790-Micromass LCT electrospray ionization mass spectrometer. High resolution mass spectra were recorded by Mr. Robin Proctor on a Walters 2790-Micromass LCT electrospray ionization mass spectrometer. m/z values are reported in Daltons.

Optical rotations were measured on a Perkin-Elmer 241 polarimeter with a path length of 1 dm and are reported with implied units of 10⁻¹ deg cm² g⁻¹. Concentrations (c) are given in g/100 ml.

Thin layer chromatography (TLC) was carried out using Merck aluminium backed sheets coated with 60F₂₅₄ silica gel. Visualization of the silica plates was achieved using a UV lamp (λ_max = 254 nm), and/or ammonium molybdate (5% in 2M H₂SO₄), or potassium permanganate (5% in 1M NaOH). Flash column chromatography was carried out using BDH PROLAB® 40-63 mm silica gel (VWR).
Anhydrous solvents were purchased from Fluka or Acros except dichloromethane which was distilled over calcium hydride. All other solvents were used as supplied (Analytical or HPLC grade), without prior purification. Distilled water was used for chemical reactions and Milli-Q water for protein modifications. Reagents were purchased from Aldrich and used as supplied. ‘Petrol’ refers to the fraction of light petroleum ether boiling in the range 40-60 °C. All reactions using anhydrous conditions were performed using flame-dried apparatus under an atmosphere of argon or nitrogen.

Protein Mass Spectrometry: Liquid chromatography-mass spectrometry (LC-MS) was performed on a Micromass LCT (ESI-TOF-MS) coupled to a Waters Alliance 2790 HPLC using a Phenomenex Jupiter C4 column (250 x 4.6 mm x 5μm). Water:acetonitrile, 95:5 (solvent A) and acetonitrile (solvent B), each containing 0.1% formic acid, were used as the mobile phase at a flow rate of 1.0 mL min⁻¹. The gradient was programmed as follows: 95% A (5 min isocratic) to 100% B after 15 min then isocratic for 5 min. The electrospray source of LCT was operated with a capillary voltage of 3.2 kV and a cone voltage of 25 V. Nitrogen was used as the nebulizer and desolvation gas at a total flow of 600 l hr⁻¹. Spectra were calibrated using a calibration curve constructed from a minimum of 17 matched peaks from the multiply charged ion series of equine myoglobin, which was also obtained at a cone voltage of 25V. Total mass spectra were reconstructed from the ion series using the MaxEnt algorithm preinstalled on MassLynx software (v. 4.0 from Waters) according to manufacturer’s instructions.
**p-Nitrophenyl 2,3,4,6-tetra-O-benzyl-1-thio-α-D-glucopyranoside 2**

Tributylphosphine (51 µl, 0.206 mmol) was added to a stirred solution of 
*p*-nitrophenyl 2,3,4,6-tetra-O-benzyl-β-D-glucopyranosyl disulfide\(^1\) (73 mg, 0.103 mmol) in anhydrous dichloromethane (2 ml) under an atmosphere of argon. The reaction mixture instantly became a dark orange red, but the colour faded rapidly to very pale yellow within 15 min. After 1 h, t.l.c. (petrol:ethyl acetate, 8:2) showed formation of a major product (R\(_f\) 0.4). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (petrol:ethyl acetate, 9:1) to afford 
*p*-nitrophenyl 2,3,4,6-tetra-O-benzyl-1-thio-α-D-glucopyranoside 2 (52 mg, 74%) as a pale yellow solid; \([\alpha]_D^{25} +184\) (c, 1 in CHCl\(_3\)); \(\nu_{\text{max}}\) (KBr disc) no significant peaks; \(\delta_H\) (400 MHz, CDCl\(_3\)) 3.58 (1H, dd, \(J_{6,6'} 1.8\) Hz, \(J_{6,6'} 10.7\) Hz, H-6), 3.69-3.76 (2H, m, H-4, H-6'), 3.90 (1H, at, \(J 9.1\) Hz, H-3), 3.98 (1H, dd, \(J_{1,2} 5.3\) Hz, \(J_{2,3} 9.6\) Hz, H-2), 4.17 (1H, ddd, \(J_{4,5} 10.0\) Hz, \(J_{5,6} 1.8\) Hz, \(J_{5,6'} 3.6\) Hz, H-5), 4.42, 4.58 (2H, ABq, \(J_{A,B} 11.9\) Hz, OCH\(_2\)Ph), 4.50, 5.00 (2H, ABq, \(J_{A,B} 10.7\) Hz, OCH\(_2\)Ph), 4.74 (2H, s, OCH\(_2\)Ph), 4.83, 4.87 (2H, ABq, \(J_{A,B} 9.6\) Hz, OCH\(_2\)Ph), 5.80 (1H, d, \(J_{1,2} 5.3\) Hz, H-1), 7.14-7.38 (20H, m, Ar-H), 7.56 (2H, d, \(J 8.8\) Hz, o-PhNO\(_2\)), 8.08 (2H, d, \(J 8.8\) Hz, p-PhNO\(_2\)); \(\delta_C\) (100.7 MHz, CDCl\(_3\)) 68.3 (t, C-6), 71.7 (d, C-5), 73.0, 73.5, 75.2, 75.9 (4 x t, 4 x OCH\(_2\)Ph), 77.1 (d, C-4), 79.4 (d, C-2), 82.4 (d, C-3), 85.3 (d, C-1), 123.8, 127.8, 127.9, 128.0, 128.1, 128.4, 128.5, 128.6, 129.1 (9 x d, 24 x Ar-C), 137.3, 137.6, 137.9, 138.4, 144.9, 145.9 (6 x s, 6 x Ar-C); \(m/z\) (ES\(^+\)) 700 (MNa\(^+\), 100%); HRMS (ES\(^+\)) Calcd. for C\(_{40}\)H\(_{39}\)NNaO\(_7\)S (MNa\(^+\)) 700.2340. Found: 700.2339; Found: C, 72.44%; H, 5.68%, N, 2.09%. C\(_{40}\)H\(_{39}\)NO\(_7\)S requires: C, 71.88%; H, 5.80%; N, 2.07%.

**A) General procedure for desulfurization reaction**

Typically, the disulfide-linked glycoaminoacid/glycopeptide was dissolved in degassed anhydrous methanol (1 mL for a 50 mg scale reaction). The phosphine reagent (2.0-2.2 equivalents) was added via microsyringe, and the resulting solution stirred under an atmosphere of argon. After t.l.c. (petrol:ethyl acetate) showed complete consumption of starting material and formation of a major product, the reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography.
Using the general procedure, \(N\text{-}\text{Acetyl-\text{DL}}\text{-cysteine-}{\text{S-(2,3,4,6-tetra-O-benzyl-\beta-D-glucopyranoside)}}\) methyl ester 4 was prepared as a thin film being a mixture of epimers (d:L, 1:1) on a 0.068 mmol (substrate) scale; Yield: 73%; \(R_t 0.4\) (petrol:ethyl acetate, 1:1); \([\alpha]_D^{18}\text{18.6 (c, 0.5 in CHCl}_3\text{)}\); \(\nu_{\text{max}}\) (thin film) 3361 (br, NH) 1744 (s, C=O) \(1661\) (s, C=O) cm\(^{-1}\); \(\delta\) (500 MHz, CDCl\(_3\)) 1.84, 1.87 (6H, 2 x s, HNC(O)CH\(_3\)D, HNC(O)CH\(_3\)L), 3.10, 3.14 (2H, 2 x dd, \(J_{CH,\alpha} 14.6\) Hz, \(J_{CH,\alpha} 7.2\) Hz, CH,\(\text{H'D', CH'H'L})\), 3.22, 3.23 (2H, dd, \(J_{CH,\alpha} 14.6\) Hz, \(J_{CH,\alpha} 4.2\) Hz, CH,\(\text{H'D', CH'H'L})\), 3.25-3.29 (2H, m, H-5D, H-5L), 3.32, 3.36 (2H, 2 x at, J 9.1 Hz, H-2D, H-2L), 3.40-3.49 (2H, m, H-4D, H-4L), 3.66-3.68 (2H, 2 x at, J 8.6 Hz, H-3D, H-3L), 3.70-3.77 (4H, m, H-6D, H-6L, H-6'D, H-6'L), 3.75, 3.78 (6H, 2 x s, OCH\(_3\)D, OCH\(_3\)L), 4.38, 4.40 (2H, 2 x d, \(J_{CH,\alpha} 9.8\) Hz, H-1D, H-1L), 4.49-4.99 (18H, m, 4 x OCH\(_3\)PhD, 4 x OCH\(_3\)PhL, \(\alpha\text{HD, }\alpha\text{HL})\) 6.85, 6.95 (2H, 2 x d, \(J_{CH,\alpha} 7.9\) Hz, HNC(O)CH\(_3\)D, HNC(O)CH\(_3\)L), 7.15-7.36 (40H, m, 20 x Ar-HD, 20 x Ar-HL); \(\delta\)C (125.8 MHz, CDCl\(_3\)) 22.5, 22.6 (2 x q, HNC(O)CH\(_3\)D, HNC(O)CH\(_3\)L), 32.8, 34.6 (2 x t, CH,\(\text{H'D', CH'H'L})\), 52.4, 52.5 (2 x d, \(\alpha\text{CD, }\alpha\text{CL})\), 52.6, 52.9 (2 x q, OCH\(_3\)D, OCH\(_3\)L), 68.7, 69.7 (2 x t, C-6D, C-6L), 73.6, 73.7, 75.1, 75.2, 75.5, 75.6, 75.7, 75.8 (8 x t, 4 x OCH\(_3\)PhD, 4 x OCH\(_3\)PhL), 77.5, 77.7 (2 x d, C-4D, C-4L), 78.5, 78.8 (2 x d, C-2D, C-2L), 81.0, 81.7 (2 x d, C-5D, C-5L), 85.6, 86.1 (2 x d, C-1D, C-1L), 86.4, 86.5 (2 x d, C-3D, C-3L), 127.6, 127.7, 127.8, 127.9, 128.0, 128.1, 128.2, 128.3, 128.4, 128.5 (10 x d, 20 x Ar-Co, 20 x Ar-Cl), 137.3, 137.5, 137.6, 137.7, 137.8, 138.2, 138.3 (7 x s, 4 x Ar-Co, 4 x Ar-Cl), 170.2, 170.3, 170.5, 170.9 (4 x s, HNC(O)CH\(_3\)D, HNC(O)CH\(_3\)L, CO\(_2\)CH\(_3\)D, CO\(_2\)CH\(_3\)L); \(m/z\) (ES\(^{+}\)) 758 (MMeCNNH\(_4\)\(^{+}\), 100%); HRMS (ES\(^{+}\)) Calcd. for C\(_{40}\)H\(_{46}\)NNaO\(_8\)S (MNa\(^{+}\)) 722.2758. Found: 722.2759.
**N-Acetyl-DL-cysteine-S-(2,3,4-tri-O-benzyl-1-thio-α-L-fucopyranoside) methyl ester 6**

Using the general procedure, *N*-acetyl-DL-cysteine-S-(2,3,4-tri-O-benzyl-1-thio-α-L-fucopyranoside) methyl ester 6 was prepared as a colourless oil being a mixture of epimers (D:L, 1:1) on a 0.048 mmol (substrate) scale; Yield: 61%; Rf 0.4 (ethyl acetate); [α]D22 -4.3 (c, 0.5 in CHCl3); υmax (thin film) 3299 (br, NH) 1746 (s, C=O) 1654 (s, C=O) cm⁻¹; δH (500 MHz, CDCl3) δH (500 MHz, CDCl3) 1.14 (1H, d, J 6.5 Hz, CH3), 1.22 (1H, d, J 6.4 Hz, CH3L), 1.97 (3H, s, HNC(O)CH3D), 1.98 (3H, s, HNC(O)CH3L), 2.77 (1H, dd, JCH,H1 14.5 Hz, JCH,H2 3.3 Hz, CH,H'D), 2.85 (1H, dd, JCH,H1 14.0 Hz, JCH,H2 3.9 Hz, CH,H'L), 3.07 (1H, dd, JCH,H1 13.8 Hz, JCH,H2 4.3 Hz, CH,H'L), 3.29 (1H, dd, JCH,H1 14.7 Hz, JCH,H2 4.7 Hz, CH,H'D), 3.63-3.67 (2H, m, H-3D, H-4D), 3.74-3.79 (2H, m, H-3L, H-4L), 3.76, 3.77 (6H, 2 x s, OCH3D, OCH3L), 4.07 (1H, q, J 6.5 Hz, H-5D), 4.45 (1H, q, J 6.5 Hz, H-5L), 4.28 (2H, dd, J1,2 5.7 Hz, J2,3 9.9 Hz, H-2D, H-2L), 4.64-4.99 (14H, m, 3 x OCH2PhD, 3 x OCH2PhL, αHd, αHL), 5.21 (1H, d, J1,2 5.6 Hz, H-1D), 5.48 (1H, d, J1,2 5.4 Hz, H-1L), 6.21 (1H, br d, JHH,H1 7.8 Hz, HNC(O)CH3D), 7.07 (1H, br d, JHH,H1 9.0 Hz, HNC(O)CH3L), 7.29-7.40 (30H, m, 15 x Ar-Hd, 15 x Ar-Hl); δC (125.8 MHz, CDC13) 14.1, 16.5 (2 x q, CH3D, CH3L), 22.7, 23.1 (2 x q, HNC(O)CH3D, HNC(O)CH3L), 35.0, 37.3 (2 x t, CH,H'D, CH,H'L), 52.1, 52.2 (2 x d, αCd, αCL), 52.5, 52.7 (2 x q, OCH2PhD, OCH2PhL), 67.8, 68.0 (2 x d, C-5D, C-5L), 72.6, 72.8, 73.5 (3 x t, 3 x OCH2PhD, 3 x OCH2PhL), 75.0, 75.9 (2 x d, C-2D, C-2L), 76.0, 76.7, 76.9, 77.2 (4 x d, C-3D, C-3L, C-4D, C-4L), 86.5 (d, C-1D, C-1L), 127.4, 127.5, 127.6, 127.7, 127.8, 127.9, 128.0, 128.2, 128.3, 128.4, 128.5, 128.6 (12 x d, 15 x Ar-Cd, 15 x Ar-CL), 138.2, 138.6 (2 x s, 3 x Ar-Cd, 3 x Ar-CL), 169.9, 170.0, 170.9 (3 x s, COOCH3D, COOCH3L, HNCOCH3D, HNCOCH3L); m/z (ES⁺) 615 (MNa⁺, 100%); HRMS (ES⁺) Calcd. for C33H38NNaO2S (MNa⁺) 616.2339. Found: 616.2340.
Using the general procedure, \(N\)-acetyl-DL-cysteine-S-(2,3,4,6-tetra-O-acetyl-\(\beta\)-D-glucopyranoside) methyl ester 8 was prepared as a colourless oil being a mixture of epimers (D,L, 1:1) on a 0.093 mmol (substrate) scale; Yield: 72%; Rf 0.3 (petrol:ethyl acetate, 1:4); [\(\alpha\)]\(D\) \(+4.0\) (c, 0.75 in CHCl\(3\)); \(\nu_{\text{max}}\) (thin film) 3383 (br, NH) 1750 (s, C=O) cm\(^{-1}\); \(\delta\) (500 MHz, CDCl\(3\)) 2.01, 2.02, 2.03, 2.04, 2.06, 2.07, 2.08, 2.11, 2.13 (30H, 9 x s, 4 x C(O)CH\(_3\)), 4 x C(O)CH\(_2\)L, HNC(O)CH\(_3\)D, HNC(O)CH\(_3\))L, 3.05, 3.08 (2H, 2 x dd, \(J_{\text{CH,HF}}\) 14.2 Hz, \(J_{\text{CH,ih}}\) 5.7 Hz, CH,H'D, CH,H'L), 3.20, 3.23 (2H, dd, \(J_{\text{CH,HF}}\) 14.1 Hz, \(J_{\text{CH,ih}}\) 3.3 Hz, CH,H'D, CH,H'L), 3.70-3.75 (2H, m, H-5D, H-5L), 3.77, 3.78 (6H, 2 x s, OCH\(_3\)D, OCH\(_3\)L), 4.17, 4.20 (2H, 2 x dd, \(J_{6,6}\) 2.1 Hz, \(J_{6,6}'\) 12.4 Hz, H-6D, H-6L), 4.24, 4.26 (2H, 2 x dd, \(J_{6,6}\) 5.4 Hz, \(J_{6,6}'\) 12.4 Hz, H-6'D, H-6'L), 4.49, 4.53 (2H, 2 x d, \(J_{1,2}\) 10.1 Hz, H-1D, H-1L), 4.78-4.84 (2H, m, \(\alpha\)HD, \(\alpha\)HL), 4.98, 4.99 (2H, 2 x at, \(J_{9,7}\) Hz, H-2D, H-2L), 5.04, 5.08 (2H, 2 x at, \(J_{9,5}\) Hz, H-4D, H-4L), 5.20, 5.23 (2H, 2 x at, \(J_{9,4}\) Hz, H-3D, H-3L), 6.46, 6.53 (2H, 2 x d, \(J_{\text{NH,ih}}\) 7.4 Hz, HNC(O)CH\(_3\)D, HNC(O)CH\(_3\)L); \(\delta\)\(_C\) (125.8 MHz, CDCl\(3\)) 20.6, 20.7 (2 x q, 4 x C(O)CH\(_3\)D, 4 x C(O)CH\(_3\)L), 22.9 (q, HNC(O)CH\(_3\)D, HNC(O)CH\(_3\)L), 31.7, 32.4 (2 x t, CH,H'D, CH,H'L), 51.8, 52.2 (2 x d, \(\alpha\)CD, \(\alpha\)CL), 52.7, 52.8 (2 x q, OCH\(_3\)D, OCH\(_3\)L), 61.8, 62.1 (2 x t, C-6D, C-6L), 68.0, 68.1 (2 x d, C-4D, C-4L), 69.7, 69.9 (2 x d, C-2D, C-2L), 73.5 (d, C-3D, C-3L), 76.0, 76.1 (2 x d, C-5D, C-5L), 83.3, 83.7 (2 x d, C-1D, C-1L), 169.3, 169.4, 169.5, 169.6, 169.8, 169.9, 170.0, 170.1, 170.6, 170.7, 170.8, 170.9 (12 x s, 4 x C(O)CH\(_3\)D, 4 x C(O)CH\(_3\)L, HNC(O)CH\(_3\)D, HNC(O)CH\(_3\)L, CO\(_2\)CH\(_3\)D, CO\(_2\)CH\(_3\)L); \(m/z\) (ES\(^+\)) 566 (MMeCNH\(_4^+\), 100%); HRMS (ES\(^+\)) Calcd. for C\(_{20}\)H\(_{29}\)NNaO\(_{12}\)S (MNa\(^+\)) 530.1303. Found: 530.1296.
\textbf{N-Acetyl-\textit{dL}-cysteinamide-S-(2,3,4,6-tetra-\textit{O}-acetyl-\textit{\beta}-\textit{D}-glucopyranoside) 10}

Using the general procedure, \textit{N}-acetyl-\textit{dL}-cysteinamide-S-(2,3,4,6-tetra-\textit{O}-acetyl-\textit{\beta}-\textit{D}-glucopyranoside) 10 was prepared as a colourless oil being a mixture of epimers (\textit{D}:\textit{L}, 1:1) on a 0.067 mmol (substrate) scale; Yield: 75%; \textit{R}t 0.3 (ethyl acetate:methanol, 95:5); $[\alpha]_D^{25}$ -1.6 (c, 0.5 in CHCl$_3$); $\nu_{\text{max}}$ (KBr disc) 3057 (br, NH NH) 1752 (s, C=O) 1643 (s, C=O) cm$^{-1}$; $\delta_H$ (500 MHz, CDCl$_3$) 2.01, 2.03, 2.04, 2.05, 2.06, 2.07, 2.08, 2.09, 2.10, 2.11 (30H, 10 x s, 4 x C(O)CH$_3$, 4 x C(O)CH$_3$, HNC(O)CH$_3$, HNC(O)CH$_3$, HNC(O)CH$_3$L), 2.69 (1H, dd, $\delta_{\text{CH, H'}}$ 14.2 Hz, $\delta_{\text{CH, H'}H}$ 7.4 Hz, CH$_3$H'0), 2.79 (1H, dd, $\delta_{\text{CH, H'}}$ 14.2 Hz, $\delta_{\text{CH, H'}H}$ 9.0 Hz, CH$_3$H'0L), 3.16 (1H, dd, $\delta_{\text{CH, H'}}$ 14.2 Hz, $\delta_{\text{CH, H'}H}$ 4.4 Hz, CH$_3$H'0L), 3.34 (1H, dd, $\delta_{\text{CH, H'}}$ 14.3 Hz, $\delta_{\text{CH, H'}H}$ 5.3 Hz, CH$_3$H'0D), 3.76 $\delta_{\text{CH, H'}H}$ 14.2 Hz, $\delta_{\text{CH, H'}H}$ 9.7 Hz, H-5L), 4.12 (1H, dd, $\delta_{\text{CH, H'}}$ 5.3 Hz, $\delta_{\text{CH, H'}H}$ 12.4 Hz, H-6L), 4.22 (1H, dd, $\delta_{\text{CH, H'}}$ 4.4 Hz, $\delta_{\text{CH, H'}H}$ 12.5 Hz, H-6D), 4.29 (1H, dd, $\delta_{\text{CH, H'}}$ 2.1 Hz, $\delta_{\text{CH, H'}H}$ 12.5 Hz, H-6'D), 4.37 (1H, dd, $\delta_{\text{CH, H'}}$ 2.0 Hz, $\delta_{\text{CH, H'}H}$ 12.4 Hz, H-6'L), 4.59 (1H, d, $\delta_{\text{H, d}}$ 9.9 Hz, H-1D), 4.62-4.67 (1H, m, $\alpha_{\text{H}}$D), 4.76-4.80 (1H, m, $\alpha_{\text{H}}$L), 4.77 (1H, d, $\delta_{\text{H, d}}$ 10.3 Hz, H-1L), 4.99 (1H, at, J 9.8 Hz, H-2L), 5.07 (1H, at, J 9.8 Hz, H-2D), 5.13 (1H, at, J 9.7 Hz, H-4L), 5.18 (1H, at, J 9.7 Hz, H-4D), 5.26, 5.27 (2H, 2 x at, J 9.3 Hz, H-3D, H-3L), 6.54, 6.63 (2H, 2 x d, $\delta_{\text{H, d}}$ 7.4 Hz, HNC(O)CH$_3$D, HNC(O)CH$_3$L); $\delta_C$ (125.8 MHz, CDCl$_3$) 20.5, 20.6, 20.7, 20.8 (4 x q, 4 x C(O)CH$_3$D, 4 x C(O)CH$_3$L), 30.0, 30.3 (2 x t, CH$_3$H'D, CH$_3$H'L), 52.2, 52.7 (2 x d, $\alpha_{\text{CD}}$, $\alpha_{\text{CL}}$), 61.6, 61.8 (2 x t, C-6D, C-6L), 67.9, 68.1 (2 x d, C-4D, C-4L), 69.2, 69.7 (2 x d, C-2D, C-2L), 73.5, 73.6 (2 x d, C-3D, C-3L), 76.0, 76.5 (2 x d, C-5D, C-5L), 83.1, 85.7 (2 x d, C-1D, C-1L), 169.4, 169.5, 169.6, 170.0, 170.1, 170.2, 170.3, 170.7 (8 x s, 4 x C(O)CH$_3$D, 4 x C(O)CH$_3$L, HNC(O)CH$_3$D, HNC(O)CH$_3$L), 172.3, 173.9 (2 x s, $\text{CONH}_2$D, $\text{CONH}_2$L); $m/z$ (ES$^+$) 515 (MNa$^+$, 100%); HRMS (ES$^+$) Calcd. for C$_{19}$H$_{28}$N$_2$NaO$_1$S (MNa$^+$) 515.1306. Found: 515.1304.
Using the general procedure, \textit{N}-Acetyl-\textit{DL}-cysteine-\textit{S}(2,3,4,6-tetra-\textit{O}-acetyl-\textit{\textbeta}-\textit{D}-galactopyranoside) methyl ester 12 was prepared as a colourless oil being a mixture of epimers (\textit{D}:\textit{L}, 1:1) on a 0.124 mmol (substrate) scale; Yield: 70%; \textit{R}_{f} 0.5 (ethyl acetate:methanol, 9:1); \textit{v}_{\text{max}} \text{ (thin film)} 3366 \text{ (br, NH)} 1749 \text{ (s, C=O)} 1664 \text{ (s, C=O) cm}^{-1};

\begin{align*}
\delta_{H} & \text{ (500 MHz, CDCl}_{3} \text{)} 1.98, 1.99, 2.05, 2.06, 2.07, 2.08, 2.09, 2.16, 2.17 \text{ (30H, 10 x s, 4 x C(O)CH}_{3} \text{D, 4 x C(O)CH}_{3} \text{L, HNC(O)CH}_{3} \text{D, HNC(O)CH}_{3} \text{L, 3.04 (1H, dd, J}_{\text{CH,}\text{H}^\alpha} \text{ 14.1 Hz, J}_{\text{CH,}\text{H}^\beta} \text{ 6.4 Hz, CH}_{3} \text{H}^\prime \text{D}), 3.09 (1H, dd, J}_{\text{CH,}\text{H}^\alpha} \text{ 14.1 Hz, J}_{\text{CH,}\text{H}^\beta} \text{ 4.4 Hz, CH}_{3} \text{H}^\prime \text{D}), 3.21 (1H, dd, J}_{\text{CH,}\text{H}^\alpha} \text{ 13.9 Hz, J}_{\text{CH,}\text{H}^\beta} \text{ 5.4 Hz, CH}_{3} \text{H}^\prime \text{L}}, 3.24 (1H, dd, J}_{\text{CH,}\text{H}^\alpha} \text{ 13.9 Hz, J}_{\text{CH,}\text{H}^\beta} \text{ 4.5 Hz, CH}_{3} \text{H}^\prime \text{L}), 3.77, 3.82 (6H, 2 x s, OCH}_{3} \text{D, OCH}_{3} \text{L}), 3.96 (2H, at, J 6.5 Hz, H-5D, H-5L), 4.13 (2H, dd, J_{5,6} 2.6 Hz, J_{6,6}^\prime 11.4 Hz, H-6D, H-6L), 4.18 (2H, dd, J_{5,6} 4.4 Hz, J_{6,6}^\prime 11.4 Hz, H-6D, H-6L), 4.49 (2H, 2 x d, J_{1,2} 10.3 Hz, H-1D, H-1L), 4.79-4.85 (2H, m, \text{CH}_{2}), 5.03 (1H, dd, J_{2,3} 10.4 Hz, J_{3,4} 3.4 Hz, H-3D), 5.07 (1H, dd, J_{2,3} 10.4 Hz, J_{3,4} 3.4 Hz, H-3L), 5.18 (1H, at, J 10.0 Hz, H-2D), 5.21 (1H, at, J 10.0 Hz, H-2L), 5.44 (2H, br s, H-4D, H-4L), 6.44 (1H, d, J 7.4 Hz, HNC(O)CH}_{3} \text{D}), 6.55 (1H, d, J 7.3 Hz, HNC(O)CH}_{3} \text{L}); \delta_{C} \text{ (125.8 MHz, CDCl}_{3} \text{)} 20.3, 20.5, 20.7, 20.8 (4 x q, 4 x C(O)CH}_{3} \text{D, 4 x C(O)CH}_{3} \text{L}), 22.9, 23.0 (2 x q, HNC(O)CH}_{3} \text{D, HNC(O)CH}_{3} \text{L}), 31.5, 32.6 (2 x t, CH}_{3} \text{H}^\prime \text{D, CH}_{3} \text{H}^\prime \text{L}), 51.7, 52.2 (2 x d, \text{CH}_{2}), 52.7, 52.8 (2 x q, OCH}_{3} \text{D, OCH}_{3} \text{L}), 61.4, 61.8 (2 x t, C-6D, C-6L), 66.8, 67.1 (2 x d, C-2D, C-2L), 67.2, 67.4 (2 x d, C-4D, C-4L), 71.6, 71.7 (2 x d, C-3D, C-3L), 74.6, 74.9 (2 x d, C-5D, C-5L), 83.6, 84.2 (2 x d, C-1D, C-1L), 169.6, 169.7, 169.8, 169.9, 169.9, 170.0, 170.1, 170.2, 170.3, 170.4, 170.6, 170.9 (12 x s, 4 x C(O)CH}_{3} \text{D, 4 x C(O)CH}_{3} \text{L, HNC(O)CH}_{3} \text{D, HNC(O)CH}_{3} \text{L, CO}_{2}\text{CH}_{3} \text{D, CO}_{2}\text{CH}_{3} \text{L}); m/z (ES) 566 (MMeCNNH}_{4}^+, 100\%); HRMS (ES) Calcd. for C_{20}H_{29}NNaO_{12}S (MNa) 530.1303. Found: 530.1321.
**N-Acetyl-DL-cysteine-S-(3,4,6-tetra-O-acetyl-2-acetamido-2-deoxy-β-D-glucopyranoside) methyl ester 14**

Using the general procedure, N-acetyl-DL-cysteine-S-(3,4,6-tetra-O-acetyl-2-acetamido-2-deoxy-β-D-glucopyranoside) methyl ester 14 was prepared as a colourless oil being a mixture of epimers (δ,δ, 6:5) on a 0.082 mmol (substrate) scale; Yield: 73%; Rf 0.3 (ethyl acetate); [α]_D^24 +15.6 (c, 1 in CHCl_3); υ_max (thin film) 3386 (br, NH) 1743 (s, C=O) 1656 (s, C=O) cm⁻¹; δ_H (400 MHz, CDCl₃) 1.96, 1.97, 1.98, 2.03, 2.04, 2.06, 2.07, 2.10, 2.11, 2.20 (30H, 10 x s, 3 x C(O)CH₃D, 3 x C(O)CH₃L, 2 x HNC(O)CH₃D, 2 x HNC(O)CH₃L), 3.02 (1H, dd, J₂₃H₂ 14.2 Hz, J₉H,₈H'D), 3.05 (1H, dd, J₂₃H₂ 14.2 Hz, J₉H,₈H'D), 3.21 (1H, dd, J₂₃H₂ 14.2 Hz, J₉H,₈H'D), 3.29 (1H, dd, J₂₃H₂ 14.2 Hz, J₉H,₈H'D), 3.67-3.73 (2H, m, H-5D, H-5L), 3.76, 3.77 (6H, 2 x s, OCH₃D, OCH₃L), 4.04 (1H, at, J₉H,₈H'D), 4.06 (1H, at, J₉H,₈H'D), 4.14 (2H, dd, J₅₆ 2.2 Hz, J₆,₇ 12.5 Hz, H-6D, H-6L), 4.24 (2H, dd, J₅₆ 2.2 Hz, J₆,₇ 12.5 Hz, H-6D, H-6L), 4.57 (1H, d, J₁₂ 10.4 Hz, H-1D), 4.59 (1H, d, J₁₂ 10.0 Hz, H-1L), 4.88-4.94 (2H, m, CH₃D, CH₃L), 5.06 (1H, at, J₉H,₈H'D), 5.10 (1H, at, J₉H,₈H'D), 5.13 (1H, at, J₉H,₈H'D), 5.16 (1H, at, J₉H,₈H'D), 5.71 (1H, d, J₉H,₈H'D), 9.4 Hz, HNC(O)CH₃D, H-2D), 5.81 (1H, d, J₉H,₈H'D), 9.3 Hz, HNC(O)CH₃D, H-2D), 6.58 (1H, d, J₉H,₈H'D), 8.1 Hz, HNC(O)CH₃D, α-Hd), 6.68 (1H, d, J₉H,₈H'D), 7.3 Hz, HNC(O)CH₃D, α-Hl); δ_C (125.8 MHz, CDCl₃) 20.5, 20.6, 20.7, 20.8 (4 x q, 3 x C(O)CH₃D, 3 x C(O)CH₃L), 22.9, 23.0, 23.2, 23.3 (4 x q, 2 x HNC(O)CH₃D, 2 x HNC(O)CH₃L), 31.9, 32.2 (2 x t, CH₃D, CH₃L), 50.8, 52.2 (2 x d, CH₃D, CH₃L), 52.7, 52.8 (2 x d, OCH₃D, OCH₃L), 52.9, 53.5 (2 x d, C-2D, C-2L), 62.0, 62.1 (2 x t, C-6D, C-6L), 67.9, 68.2 (2 x d, C-4D, C-4L), 73.5, 73.8 (2 x d, C-3D, C-3L), 76.1, 76.3 (2 x d, C-5D, C-5L), 84.2, 84.3 (2 x d, C-1D, C-1L), 169.2, 169.3, 169.4, 170.1, 170.4, 170.5, 170.6, 170.7, 170.8, 170.9, 171.0, 171.3 (12 x s, 3 x C(O)CH₃D, 3 x C(O)CH₃L, 2 x HNC(O)CH₃D, 2 x HNC(O)CH₃L, CO₂CH₃D, CO₂CH₃L); m/z (ES⁺) 565 (MMeCNNH₄⁺, 100%). HRMS (ES⁺) Calcd. for C₂₀H₂₉N₂O₁₁S (MNa⁺) 529.1463. Found: 529.1462.
**N-Acetyl-DL-cysteine-S-(β-D-glucopyranoside) methyl ester 16**

Using the general procedure, **N-acetyl-DL-cysteine-S-(β-D-glucopyranoside) methyl ester 16** was prepared as a white foam being a mixture of epimers (D:L, 1:1) on a 0.064 mmol (substrate) scale; Yield: 68%; R<sub>t</sub> 0.3 (ethyl acetate:iso-propanol:water, 5:3:1); [α]<sub>D</sub><sup>22</sup> +0.0 (c, 0.5 in MeOH); <i>υ</i><sub>max</sub> (thin film) 3442 (br, NH OH) 1643 (s, C=O) cm<sup>-1</sup>; δ<sub>H</sub> (500 MHz, CD<sub>3</sub>OD) 2.03, 2.04 (6H, 2 x s, HNC(O)C=O); 3.09 (1H, dd, J<sub>CH,CH</sub> 14.3 Hz, J<sub>CH,rH</sub> 8.3 Hz, CH<sub>2</sub>H<sub>2</sub>D), 3.26-3.40 (7H, m, H-2D, H-2L, H-3D, H-3L, H-4D, H-4L, CH<sub>2</sub>H<sub>2</sub>D), 3.59-3.66 (2H, m, H-5D, H-5L), 3.69 (1H, dd, J<sub>5.6</sub> 6.0 Hz, J<sub>6.6</sub> 13.0 Hz, H-6D), 3.76 (6H, s, OCH<sub>3</sub>), 9.7 Hz, H-1D), 4.43 (1H, d, J<sub>1.2</sub> 9.7 Hz, H-1L), 4.69-4.72 (1H, m, αHD), 4.76-4.78 (1H, m, αHL); δ<sub>C</sub> (125.8 MHz, CD<sub>3</sub>OD) 22.4, 22.5 (2 x q, HNC(O)CH<sub>2</sub>D), 31.9, 33.0 (2 x t, CH<sub>2</sub>H<sub>2</sub>D, CH<sub>2</sub>H<sub>2</sub>L), 52.9, 54.3 (2 x d, αCD, αCL), 54.6, 55.5 (2 x q, OCH<sub>3</sub>D, OCH<sub>3</sub>L), 62.7, 62.9 (2 x t, C-6D, C-6L), 71.6, 71.8 (2 x d, C-2D, C-2L), 74.2, 74.4 (2 x d, C-5D, C-5L), 78.1, 79.5 (2 x d, C-4D, C-4L), 82.1, 82.3 (2 x d, C-3D, C-3L), 86.8, 87.8 (2 x d, C-1D, C-1L), 172.7, 173.5 (2 x s, HNC(O)CH<sub>3</sub>D, HNC(O)CH<sub>3</sub>L CO<sub>2</sub>CH<sub>3</sub>D, CO<sub>2</sub>CH<sub>3</sub>L); m/z (ES<sup>+</sup>) 362 (M<sup>Na</sup><sup>+</sup>, 100%); HRMS (ES<sup>+</sup>) Calcd. for C<sub>12</sub>H<sub>21</sub>NNaO<sub>3</sub>S (M<sup>Na</sup><sup>+</sup>) 362.0880. Found: 362.0870.

**N-Acetyl-DL-cysteine-S-(2-acetamido-2-deoxy-β-D-glucopyranoside) methyl ester 18**

Using the general procedure, **N-acetyl-DL-cysteine-S-(2-acetamido-2-deoxy-β-D-glucopyranoside) methyl ester 18** was prepared as a white amorphous solid being a mixture of epimers (D:L, 1:1) on a 0.072 mmol (substrate) scale; Yield: 74%; R<sub>t</sub> 0.3 (ethyl acetate:iso-propanol:water, 5:3:1); [α]<sub>D</sub><sup>18</sup> +1.6 (c, 1 in MeOH); <i>υ</i><sub>max</sub> (KBr disc) 3413 (br, NH OH) 1735 (s, C=O) 1646 (s, C=O) cm<sup>-1</sup>; δ<sub>H</sub> (500 MHz, CD<sub>3</sub>OD) 1.99,
2.00, 2.04, 2.18 (12H, 4 x s, 2 x HNC(O)CH$_3$D, 2 x HNC(O)CH$_3$L), 2.83 (1H, dd, $J_{CHH'}$ 14.2 Hz, $J_{CHH'}$ 9.1 Hz, CH$_3$H'D), 3.07 (1H, dd, $J_{CHH'}$ 14.1 Hz, $J_{CHH'}$ 7.8 Hz, CH$_3$H'L), 3.11 (1H, dd, $J_{CHH'}$ 14.2 Hz, $J_{CHH'}$ 5.5 Hz, CH$_3$H'L), 3.33-3.37 (3H, m, CH$_3$H'D, H-4D), 3.48 (2H, at, $J$ 9.0 Hz, H-3D, H-3L), 3.54-3.59 (1H, m, H-5D), 3.74, 3.75 (6H, 2 x s, OCH$_3$D, OCH$_3$L), 3.66-3.76 (4H, m, H-2L, H-5L, H-6D, H-6L), 3.80-3.97 (3H, m, H-2D, H-6'D, H-6'L), 4.52 (1H, d, $J_{1,2}$ 10.3 Hz, H-1D), 4.58 (1H, d, $J_{1,2}$ 10.3 Hz, H-1L), 4.67-4.76 (2H, m, $\alpha$H), $\alpha$H); $\delta$C (125.8 MHz, CD$_3$OD) 22.5, 22.6, 23.0, 25.3 (4 x q, 2 x HNC(O)CH$_3$D, 2 x HNC(O)CH$_3$L), 32.0, 33.3 (2 x t, CH,H'D, CH,H'L), 52.9, 53.0 (2 x q, OCH$_3$D, OCH$_3$L), 54.1, 54.5 (2 x d, $\alpha$CD, $\alpha$CL), 55.8, 56.3 (2 x d, C-2D, C-2L), 62.7, 62.8 (2 x t, C-6D, C-6L), 73.0, 73.7 (2 x d, C-4D, C-4L), 77.1, 77.2 (2 x d, C-5D, C-5L), 82.2, 82.4 (2 x d, C-3D, C-3L), 85.3, 86.8 (2 x d, C-1D, C-1L), 172.7, 172.8, 173.5, 173.6, 173.7, 173.8 (6 x s, 2 x HNC(O)CH$_3$D, 2 x HNC(O)CH$_3$L, CO$_2$CH$_3$D, CO$_2$CH$_3$L); m/z (ES$^+$) 403 (MNa$^+$, 100%); HRMS (ES$^+$) Calcd. for C$_{14}$H$_{22}$N$_2$NaO$_8$S (MNa$^+$) 403.1146. Found: 403.1141.

$N$-Acetyl-DL-cysteine-S-(2,3,4,6-tetra-$O$-acetyl-$\beta$-$D$-glucopyranoside)-$O$-tert-butyl-L-serine-glycine ethyl ester 20

Using the general procedure, $N$-acetyl-DL-cysteine-S-(2,3,4,6-tetra-$O$-acetyl-$\beta$-$D$-glucopyranoside)-$O$-tert-butyl-L-serine-glycine ethyl ester 20 was prepared as a colourless oil being a mixture of epimers (d:L, 1:1) on a 0.066 mmol (substrate) scale;
Yield: 73%; Rf 0.6 (petrol:ethyl acetate, 1:4); $[\alpha]^2 D_{22} +0.1$ (c, 0.5 in CHCl$_3$); $\nu$max (thin film) 3334 (br, NH) 1751 (s, C=O) 1661 (s, C=O) cm$^{-1}$; $\delta$H (500 MHz, CDCl$_3$) 1.19, 1.22 (18H, 2 x s, C(CH$_3$)$_3$D, C(CH$_3$)$_3$L), 1.26 (6H, t, $J$ 7.2 Hz, OCH$_2$CH$_3$D, OCH$_2$CH$_3$L), 1.99, 2.01, 2.03, 2.04, 2.05, 2.06, 2.07, 2.08, 2.09, 2.12 (30H, 10 x s, 4 x C(O)CH$_3$D, 4 x C(O)CH$_3$L, HNC(O)CH$_3$D, HNC(O)CH$_3$L), 2.90 (2H, 2 x dd, $J_{CHH'}$ 14.0 Hz, $J_{CHH'}$ 9.5 Hz, CH$_3$H'cysD, CH$_3$H'cysL), 3.11 (2H, dd, $J_{CHH'}$ 14.0 Hz, $J_{CHH'}$ 4.9 Hz, CH$_3$H'cysD, CH$_3$H'cysL), 3.35-3.48 (4H, m, CH,H'serD, CH,H'serL), 3.75-3.80 (1H, m, H-5D), 3.85-3.93 (1H, m, H-5L), 4.01-4.06 (4H, m, 2 x HglyD, 2 x HglyL), 4.16-4.26 (6H, m, OCH$_2$CH$_3$D, OCH$_2$CH$_3$L, H-6D, H-6L), 4.38 (1H, dd, $J_{5,6}$ 2.0 Hz, $J_{6,6}$ 12.6 Hz, H-6'D), 4.41 (1H, dd, $J_{5,6}$ 2.0 Hz, $J_{6,6}$ 12.6 Hz, H-6'L), 4.46-4.56 (2H, m, $\alpha$HserD,
\( \alpha \)HserL, 4.59 (1H, d, \( J_{1,2} \) 9.8 Hz, H-1D), 4.77 (1H, d, \( J_{1,2} \) 10.2 Hz, H-1L), 4.85-4.88 (2H, m, \( \alpha \)HcysD, \( \alpha \)HcysL), 5.03 (2H, at, \( J \) 9.8 Hz, H-2D, H-2L), 5.11 (1H, at, \( J \) 9.7 Hz, H-4D), 5.17 (1H, at, \( J \) 9.7 Hz, H-4L), 5.26 (2H, at, \( J \) 9.9 Hz, H-3D, H-3L), 6.51 (2H, d, \( J_{\text{NH},\text{uH}} \) 7.4 Hz, HNC(O)CH\( _3 \)cysD, HNC(O)CH\( _3 \)cysL), 6.65 (2H, d, \( J_{\text{NH},\text{uH}} \) 6.9 Hz, HNC(O)CH\( _3 \)serD, HNC(O)CH\( _3 \)serL), 7.44 (2H, d, \( J_{\text{NH},\text{uH}} \) 7.8 Hz, HNC(O)CH\( _3 \)glyD, HNC(O)CH\( _3 \)glyL); \( \delta _C \) (125.8 MHz, CDCl\( _3 \)) 14.1, 14.2 (2 x q, OCH\( _2 \)CH\( _3 \)D, OCH\( _2 \)CH\( _3 \)L), 20.5, 20.6, 20.7, 20.8, 21.0 (5 x q, 4 x C(O)CH\( _3 \)D, 4 x C(O)CH\( _3 \)L), 22.9, 23.0 (2 x q, HNC(O)CH\( _3 \)D, HNC(O)CH\( _3 \)L), 27.3, 27.4 (2 x q, C(CH\( _3 \))\( _3 \)D, C(CH\( _3 \))\( _3 \)L), 34.6 (2 x t, CH\( _2 \)H’cysD, CH\( _2 \)H’cysL), 41.2, 41.4 (2 x t, \( \alpha \)CglyD, \( \alpha \)CglyL), 52.4, 53.1, 53.4, 54.1 (4 x d, \( \alpha \)CcysD, \( \alpha \)CcysL, \( \alpha \)CserD, \( \alpha \)CserL), 60.4, 60.9, 61.1, 61.3, 61.4, 62.3 (6 x t, OCH\( _2 \)CH\( _3 \)D, OCH\( _2 \)CH\( _3 \)L, C-6D, C-6L, CH\( _2 \)H’serD, CH\( _2 \)H’serL), 67.8, 68.3 (2 x d, C-4D, C-4L), 69.0, 69.7 (2 x d, C-2D, C-2L), 73.6, 74.1 (d, C-3D, C-3L), 76.4, 76.5 (2 x d, C-5D, C-5L), 83.1, 85.6 (2 x d, C-1D, C-1L), 169.0, 169.2, 169.4, 169.5, 169.6, 169.7, 169.8, 169.9, 170.0, 170.1, 170.2, 170.4, 170.9, 171.1 (14 x s, 4 x C(O)CH\( _3 \)D, 4 x C(O)CH\( _3 \)L, HNC(O)CH\( _3 \)D, HNC(O)CH\( _3 \)L, C(O)HNC\( \alpha \)cserD, C(O)HNC\( \alpha \)cserL, C(O)HNC\( \alpha \)cglyD, C(O)HNC\( \alpha \)cglyL, CO\( _2 \)CH\( _3 \)D, CO\( _2 \)CH\( _3 \)L); \( m/z \) (ES\( ^{+} \)) 780 (MM+CH\( _3 \)H\( _4 \)S, 100%); HRMS (ES\( ^{+} \)) Calcd. for C\( _{30} \)H\( _{47} \)NaO\( _{13} \)S (MNa\( ^{+} \)) 744.2620. Found: 744.2608.

\( N \)-Acetyl-\( \beta \)-cysteine-\( \text{S-} \) (2,3,4,6-tetra-\( \text{O} \)-acetyl-\( \beta \)-D-galactopyranoside)-glycine-\( \text{O-tert} \)-butyl-\( \beta \)-threonine-glycine ethyl ester 22

Using the general procedure, \( N \)-acetyl-\( \beta \)-cysteine-\( \text{S-} \) (2,3,4,6-tetra-\( \text{O} \)-acetyl-\( \beta \)-D-galactopyranoside)-glycine-\( \text{O-tert} \)-butyl-\( \beta \)-threonine-glycine ethyl ester 22 was prepared as a colourless oil being a mixture of epimers (D:L, 1:1) on a 0.057 mmol (substrate) scale; Yield: 67%; \( \gamma \) 0.5 (DCM:methanol, 9:1); [\( \alpha \])\( _D \)\( ^{18} \).-1.7 (c, 0.5 in CHCl\( _3 \)); \( \nu _{\text{max}} \) (thin film) 3382 (br, NH) 1725 (s, C=O) 1652 (s, C=O) cm\(^{-1} \); \( \delta _H \) (500 MHz, CDCl\( _3 \)) 1.05, 1.07 (6H, 2 x d, \( J \) 6.5 Hz, CHCH\( _4 \)thrd, CHCH\( _4 \)thrl), 1.28-1.54 (24H, m, C(CH\( _3 \))\( _3 \)D, C(CH\( _3 \))\( _3 \)L, OCH\( _2 \)CH\( _3 \)D, OCH\( _2 \)CH\( _3 \)L), 1.98, 1.99, 2.00, 2.01, 2.05, 2.06, 2.07, 2.09 (24H, 8 x s, 4 x C(O)CH\( _3 \)D, 4 x C(O)CH\( _3 \)L), 2.18, 2.22 (6H, 2 x s, HNC(O)CH\( _3 \)D, HNC(O)CH\( _3 \)L), 2.87-3.00 (3H, m, CH\( _2 \)H’cysD, CH\( _2 \)H’cysL, CH\( _2 \)H’cysL), 3.13 (1H, dd, \( J_{\text{CH},\text{H}} \) 14.4 Hz, \( J_{\text{CH},\text{uH}} \) 5.4 Hz, CH\( _2 \)H’cysD), 3.53-4.23 (16H, m, H-5D, H-5L, H-6D, H-6L, H-6’d, H-6’L, OCH\( _2 \)CH\( _3 \)D, OCH\( _2 \)CH\( _3 \)L, 2 x \( \alpha \)HglyD, 2 x \( \alpha \)HglyL, CHCH\( _4 \)thrd, CHCH\( _4 \)thrl),
4.49 (2H, dd, J 3.6 Hz, J 6.2 Hz, αHthrD, αHthrL), 4.66 (2H, 2 x d, J_{1,2} 10.1 Hz, H-1D, H-1L), 4.77 (1H, dd, J 3.8 Hz, J 6.3 Hz, αHcysD), 4.83 (1H, dd, J 3.6 Hz, J 5.8 Hz, αHcysL), 4.99-5.47 (6H, m, H-2D, H-2L, H-3D, H-3L, H-4D, H-4L), 6.60, 6.97, 7.10, 7.17, 7.37, 7.66 (6H, 6 x d, J 4.2 Hz, J 5.4 Hz, J 5.8 Hz, J 8.3 Hz, 4 x HNC(O)CH₃D, 4 x HNC(O)CH₃L); δC (125.8 MHz, CDCl₃) 14.1, 14.2 (2 x q, OCH₂C₃H₇D, OCH₂C₃H₇L), 17.3, 17.4 (2 x q, CH₂CH₃thrD, CH₂CH₃thrL), 20.5, 20.6, 20.7, 20.8, 20.9, 21.0 (6 x q, 4 x C(O)CH₃D, 4 x C(O)CH₃L), 22.9, 23.0 (2 x q, HNC(O)CH₃D, HNC(O)CH₃L), 28.1, 28.2 (6 x q, C(CH₃)₃D, C(CH₃)₃L), 41.3, 41.4, 41.5, 41.6, 41.7, 41.8 (6 x t, 2 x CH₂H’glyD, 2 x CH₂H’glyL, CH₂H’cysD, CH₂H’cysL), 52.3, 52.7 (2 x d, αCcysD, αCcysL), 57.5, 57.6 (2 x d, αCthrD, αCthrL), 61.4, 61.5 (2 x t, OCH₂C₃H₇D, OCH₂C₃H₇L), 62.0, 62.4 (2 x t, C-6D, C-6L), 65.9, 66.1, 66.4, 66.7, 67.2, 67.6 (6 x d, C-2D, C-2L, C-3D, C-3L, C-4D, C-4L), 71.3, 71.6 (2 x s, C(CH₃)₃D, C(CH₃)₃L), 74.9, 75.4 (2 x d, C-5D, C-5L), 75.7, 75.9 (2 x d, CH₂CH₃thrD, CH₂CH₃thrL), 83.1, 84.9 (2 x d, C-1D, C-1L), 169.9, 170.1, 170.3, 170.8, 170.9, 172.4, 172.5 (7 x s, 4 x C(O)CH₃D, 4 x C(O)CH₃L, HNC(O)CH₃D, HNC(O)CH₃L); m/z (ES⁺) 851 (MMeCNNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C₃₃H₅₂N₄NaO₁₆S (MNa⁺) 815.2991. Found: 815.2990.
Protein Modification

**Preparation of SBL-S156C-SS-Glc(OAc)$_4$ 23**

SBL-S156C mutant 25 (2.5 mg) was dissolved in buffer (500 µL, 70 mM CHES, 5 mM MES, 2 mM CaCl$_2$, pH 9.5). A solution of 2,3,4,6-tetra-O-acetyl-β-D-glucopyranoside phenylthiosulfonate 26 (100 µL of a 10 mM solution in acetonitrile) was added and placed on an end-over-end rotator. After 30 min, the reaction mixture was purified by size exclusion chromatography Sephadex® G25 column against the above buffer. The protein fraction was analysed by LC-mass spectrometry to afford the modified protein 23 (calculated mass, 27078; observed mass, 27075).

**Scheme S4.**

**Figure S1.** ESI-MS spectrum of SBL-S156C-SS-Glc(OAc)$_4$ 23.

**Desulfurization of SBL-S156C-SS-Glc(OAc)$_4$ 23**

To a degassed solution of SBL-S156C-SS-Glc(OAc)$_4$ 23 (250 µL of a 2 mg/mL solution in buffer (70 mM CHES, 5 mM MES, 2 mM CaCl$_2$, pH 9.5)) hexamethylphosphorus triamide was added (6.0 µL, 2 equivalent). The reaction was placed on an end-over-
end rotator. After 12 h, the reaction mixture was purified by size exclusion chromatography Sephadex® G25 column against the above buffer and analysed by LC-mass spectrometry to afford SBL-S156C-S-Glc(OAc)₄ 24 (calculated mass, 27046; observed mass 27044).

Figure S2. ESI-MS spectrum of SBL-S156C-S-Glc(OAc)₄ 24.

Treatment of 24 with TCEP

To a degassed solution of SBL-S156C-S-Glc(OAc)₄ 24 (80 µL of a 2 mg/mL solution in buffer (70 mM CHES, 5 mM MES, 2 mM CaCl₂, pH 9.5)) tris(2-carboxyethyl) phosphine (TCEP) (0.4 µL of a 200 mmol aqueous solution, pH 7.0). The reaction was placed on an end-over-end rotator for 10 min, purified by size exclusion chromatography Sephadex® G25 column against the above buffer and analysed by LC-mass spectrometry and the thioether-linked glycoprotein 24 was shown to be stable under reducing conditions (calculated mass, 27044; observed mass 27046).

Figure S3. ESI-MS spectrum of SBL-S156C-S-Glc(OAc)₄ 24 when treated with TCEP.
Treatment of 23 with TCEP

Scheme S7.

To a degassed solution of SBL-S156C-SS-Glc(OAc)$_4$ 23 (150 µL of a 2 mg/mL solution in buffer (70 mM CHES, 5 mM MES, 2 mM CaCl$_2$, pH 9.5)) tris(2-carboxyethyl) phosphine (TCEP) (1 µL of a 200 mmol aqueous solution, pH 7.0). The reaction was placed on an end-over-end rotator for 10 min, purified by size exclusion chromatography Sephadex® G25 column against the above buffer and analysed by LC-mass spectrometry to afford SBL-S156C 25 (calculated mass, 26714; observed mass 26718).

Figure S4. ESI-MS spectrum of SBL-S156C 25, formed from reaction of 23 with TCEP.

Trypsin digestion and MALDI analysis of 24

Thioether protein 24 (20 µl of 1mg/mL in 100 mM NH$_4$HCO$_3$, pH 8.0) was incubated with 1µg of trypsin (Promega) overnight at 37 °C. Peptides were extracted and desalted with a C18 ZipTip (Millipore Corp.) according to the manufacturer’s specifications. Eluted peptides were mixed 1:1 (v/v) with a solution of α-cyano-4-hydroxycinnamic acid (saturated in 50% MeCN in H$_2$O with 0.1% TFA). From this mixture, 2 µl were spotted onto a steel target and analyzed in positive mode on a Waters Micro-Mass MALDI. A three point calibration curve of Angiotensin (1296.5), Renin (1759.0), and ACTH (18-34 clip, 2465.7) was applied to data with ACTH as the lock mass. 8 of 13 predicted peptides of 24 were observed including the peptide containing Cys156Glc(OAc)$_4$. (2312 calculated, 2312 found).
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Disulfide-linked glycoaminoacids and glycopeptides - prepared using glycoPTS\textsuperscript{2} or glycoSeS\textsuperscript{3} strategy

Preparation of Sodium phenylthiosulfonate (Na-PTS)\textsuperscript{4} 26

\[
\text{Na-SO}_2\text{O-SNa} \xrightarrow{\text{elemental sulphur, anhydrous pyridine}} \text{Na-SO}_2\text{O-SNa} \ \ (83\%)
\]

Sodium benzenesulfinate (10.0 g, 61 mmol) and elemental sulphur (1.9 g, 61 mmol) was dissolved in anhydrous pyridine (60 mL) to give a yellow solution. The reaction was stirred under argon and after 1 h gave a white suspension. The reaction was filtered and washed with anhydrous diethyl ether. Recrystalisation from anhydrous ethanol afforded sodium phenylthiosulfonate 26 (9.8 g, 83%) as a white crystalline solid; m.p. 282-284 °C (ethanol) [Lit. 287 °C]\textsuperscript{4}; δ\textsubscript{H} (400 MHz, D\textsubscript{2}O) 3.26 (3H, s, CH\textsubscript{3}); m/z (ES\textsuperscript{-}) 173 (M-Na\textsuperscript{+}, 100%).

Synthesis of N-acetyl-L-cysteine-methyl ester\textsuperscript{5} 27

\[
\text{AcHN-SH} \xrightarrow{} \text{AcN-OMe}
\]

Thionyl chloride (2 mL, 26.99 mmol) was carefully added to a solution of N-acetyl-L-cysteine (4 g, 24.54 mmol) in anhydrous methanol, and the resulting mixture was stirred for 3 h at RT. The reaction mixture was concentrated in vacuo, diluted with ethyl acetate (75 mL), and washed with sodium hydrogen carbonate (50 mL of a saturated aqueous solution). The aqueous layer was re-extracted with ethyl acetate (2 x 75 mL). The organic layers were combined, dried (MgSO\textsubscript{4}), filtered, and concentrated in vacuo to afford N-acetyl-L-cysteine methyl ester 27 (2.32 g, 54%) as a white crystalline solid; m.p. 78-80 °C (ethyl acetate) [Lit. 79-80 °C (ethyl acetate)]\textsuperscript{5}; [\textalpha]_{D}\textsuperscript{22} -23.2 (c, 1 in CD\textsubscript{3}OD) [Lit. [\textalpha]_{D}\textsuperscript{25} -24 (c, 1 in MeOH)]\textsuperscript{5}; δ\textsubscript{H} (400 MHz, CDCl\textsubscript{3}) 1.34 (1H, t, J 9.0 Hz, SH), 2.08 (3H, s, COCH\textsubscript{3}), 3.00-3.04 (2H, m, CH\textsubscript{2}), 3.80 (3H, s, CO\textsubscript{2}CH\textsubscript{3}), 4.88-4.92 (1H, m, αH), 6.40 (1H, br s, NH); m/z (ES\textsuperscript{-}) 176 (M-H\textsuperscript{+}, 100%).
Synthesis of N-Acetyl-L-cysteine (2,3,4,6-tetra-O-benzyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 3

Methyl 2,3,4,6-tetra-O-benzyl-α-D-glucopyranoside 29

Methyl α-D-glucopyranoside 28 (25 g, 129 mmol) was dissolved in anhydrous DMF (250 mL), and sodium hydride (60% dispersed in mineral oil) (31 g, 774 mmol) was added portionwise for a period of 10 min at 0 °C. Benzyl bromide (92 mL, 770 mmol) was then added dropwise and the mixture left to stir under an atmosphere of argon at room temperature. After a 24 h period, t.l.c. (petrol:ethyl acetate, 3:1) indicated the formation of a product (R_f 0.4) with complete consumption of the starting material (R_f 0). The reaction mixture was quenched by the slow addition of methanol (150 mL) and stirred for 30 min, at which point the resulting solution was concentrated in vacuo. The residue was dissolved in DCM (800 mL), washed with water (2 x 500 mL), and brine (500 mL), dried (MgSO_4), filtered and concentrated in vacuo. Purification by flash column chromatography (petrol:ethyl acetate, 6:1) afforded methyl 2,3,4,6-tetra-O-benzyl-α-D-glucopyranoside 29 (51.5 g, 72%) as a viscous yellow oil; [α]_D^21 +19.3 (c, 1 in CHCl_3) [Lit. [α]_D^{22} +21.2 (c, 1 in H_2O)]^7; δ_H (400 MHz, CDCl_3) 3.39 (3H, s, OCH_3), 3.57 (1H, dd, J_1,2 3.6 Hz, J_2,3 9.6 Hz, H-2), 3.63 (1H, d, J 9.6 Hz, H-4), 3.64 (1H, dd, J_5,6 2.3 Hz, J_6,6' 13.1 Hz, H-6), 3.71-3.78 (2H, m, H-5, H-6'), 4.00 (1H, at, J 9.6 Hz, J_3,4 9.2 Hz, H-3), 4.48, 4.84 (2H, ABq, J_A,B 11.0 Hz, OCH_2Ph), 4.49, 4.68 (2H, ABq, J_A,B 12.1 Hz, OCH_2Ph), 4.59, 4.81 (2H, ABq, J_A,B 8.9 Hz, OCH_2Ph), 4.64 (1H, d,
J₁,₂ 3.6 Hz, H-1), 4.91, 4.92 (2H, ABq, Jₐ,b 10.9 Hz, OCH₂Ph), 7.13-7.16 (2H, m, Ar-H), 7.27-7.39 (18H, m, Ar-H); m/z (ES⁺) 577 (MNa⁺, 50%) 613 (MMeCNNH₄⁺, 100%).

2,3,4,6-Tetra-O-benzyl-D-glucopyranose 30

Methyl 2,3,4,6-tetra-O-benzyl-α-D-glucopyranoside 29 (15.33 g, 27.64 mmol) was dissolved in glacial acetic acid (300 mL). The mixture was heated to 90 °C with stirring, at which point sulfuric acid (2M, 75 mL) was added. After a further 2 h period, sulfuric acid (2M, 75 mL) was added. After 22 h, t.l.c. (petrol:ethyl acetate, 4:1) indicated formation of a major product (Rf 0.4) and complete consumption of starting material (Rf 0.5). Water (200 mL) was added and the reaction mixture cooled to 0 °C, at which point a crystalline solid precipitated. The crystals were filtered off and washed with methanol (80% V/V) affording 2,3,4,6-tetra-O-benzyl-D-glucopyranose 30 (10.25 g, 68%) as a white crystalline solid, being a mixture of anomers (α:β, 1:1); m.p. 148-150 °C (ethyl acetate/petrol) [Lit. 151-152 °C]; [α]D⁺ 20.7 (c, 1 in CHCl₃) [Lit. [α]D⁺ 22 (c, 1.0 in CHCl₃)]; δH (400 MHz, CDCl₃) 3.42 (1H, dd, J₁,₂ 7.8 Hz, J₂,₃ 9.1 Hz, H-2β), 3.47-3.74 (8H, m, H-4α, H-6α, H-6'α, H-3β, H-4β, H-5β, H-6β, H-6'β), 3.60 (1H, dd, J₁,₂ 3.7 Hz, J₂,₃ 9.5 Hz, H-2α), 3.99 (1H, at, J₂,₃ 9.5 Hz, J₃,₄ 9.2 Hz, H-3α), 4.05 (1H, ddd, J₄,₅ 10.1 Hz, J₅,₆ 3.8 Hz, J₆,₆' 2.1 Hz, H-5α), 4.48-4.97 (16H, m, 4 x OCH₂Phα, 4 x OCH₂Phβ), 4.73 (1H, d, J₁,₂ 7.8 Hz, H-1β), 5.24 (1H, d, J₁,₂ 3.7 Hz, H-1α), 7.15-7.38 (40H, m, 20 x Ar-Hα, 20 x Ar-Hβ).

2,3,4,6-Tetra-O-benzyl-α-D-glucopyranose bromide 31

2,3,4,6-Tetra-O-benzyl-D-glucopyranose 30 (4.0 g, 7.39 mmol) was dissolved in anhydrous DCM (24 mL) and anhydrous DMF (2 mL). The resulting solution was cooled to 0 °C, at which point oxalyl bromide (16 mL, 2M in DCM, 29.56 mmol) was added dropwise. The reaction mixture was allowed to warm to room temperature and left to stir under an atmosphere of argon. After 2 h, t.l.c. (petrol:ethyl acetate, 1:1) indicated the formation of a major product (Rf 0.6). The reaction was cooled to 0 °C and quenched with ice cold water (60 mL) added over a 5 min period. The mixture was
partitioned between DCM (80 mL) and water. The aqueous layer was re-extracted with DCM (3 x 80 mL), and the combined organic layers were washed with brine (150 mL), dried (MgSO₄), filtered and concentrated in vacuo to afford 2,3,4,6-tetra-O-benzyl-α-D-glucopyranose bromide 31 (4.20 g, 94%) as a crude yellow oil which was used without any further purification; δ_H (400 MHz, CDCl₃) 3.55 (1H, dd, J₁,₂ 3.7 Hz, J₂,₃ 9.2 Hz, H-2), 3.66 (1H, dd, J₅,₆ 1.8 Hz, J₅,₆' 11.0 Hz, H-6), 3.76-3.80 (1H, m, H-4, H-6'), 4.04 (1H, at, J₂,₃ 9.2 Hz, J₃,₄ 9.2 Hz, H-3), 4.55-5.00 (8H, m, 4 x OCH₂Ph), 6.44 (1H, d, J₁,₂ 3.7 Hz, H-1), 7.14-7.42 (20H, m, Ar-H).

2,3,4,6-Tetra-O-benzyl-β-D-glucopyranosyl phenylthiosulfonate² 32

2,3,4,6-Tetra-O-benzyl-α-D-glucopyranose bromide 31 (3.5 g, 5.804 mmol) and sodium phenylthiosulfonate 26 (4.41 g, 22.47 mmol) were dissolved in anhydrous dioxane (90 mL). The resulting reaction mixture was heated to 70 ºC under an atmosphere of argon. After a 24 h period, t.l.c. (petrol:ethyl acetate, 2:1) indicated the formation of a major product (Rₖ 0.5) with complete consumption of the starting material (Rₖ 0.6). The reaction mixture was cooled to room temperature and filtered. The precipitate was washed with petrol/ethyl acetate and the filtrate concentrated in vacuo. The residue was purified by flash column chromatography (petrol:ethyl acetate, 4:1) to afford 2,3,4,6-tetra-O-benzyl-D-glucopyranosyl phenylthiosulfonate 32 (3.26 g, 81%) as a white viscous gum being a mixture of anomers (α:β, 1:2). Selective recrystallisation from ethyl acetate/petrol afforded pure 2,3,4,6-tetra-O-benzyl-β-D-glucopyranosyl phenylthiosulfonate X as a white crystalline solid; m.p. 106-108 ºC (ethyl acetate/petrol) [Lit. 106-108 ºC (ethyl acetate/petrol)]²; [α]D²³ +47.8 (c, 1 in CHCl₃) [Lit. [α]D²² +21.4 (c, 0.35 in CHCl₃)]²; δ_H (400 MHz, CDCl₃) 3.45 (1H, ddd, J₄,₅ 9.6 Hz, J₅,₆ 1.6 Hz, J₅,₆' 3.6 Hz, H-5), 3.49 (1H, dd, J₅,₆ 1.4 Hz, J₆,₆' 11.7 Hz, H-6), 3.54 (1H, dd, J₂,₃ 9.9 Hz, J₂,₃ 8.7 Hz, H-2), 3.57 (1H, dd, J₅,₆ 3.6 Hz, J₆,₆' 11.6 Hz, H-6'), 3.62 (1H, at, J₉ 9.4 Hz, H-3), 3.72 (1H, at, J₈ 8.8 Hz, H-4), 4.34-4.90 (8H, m, 4 x OCH₂Ph), 5.13 (1H, d, J₁,₂ 10.0 Hz, H-1), 7.09-7.15 (3H, m, Ar-H), 7.27-7.54 (20H, m, Ar-H), 7.90-7.98 (2H, m, Ar-H); m/z (ES⁺) 718 (MNa⁺, 20%) 755 (MMeCNNH₄⁺, 100%).
**N-Acetyl-L-cysteine (2,3,4,6-tetra-O-benzyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 3**

2,3,4,6-Tetra-O-benzyl-β-D-glucopyranosyl phenylthiosulfonate 32 (1.10 g, 1.581 mmol) and triethylamine (74 µL, 0.527 mmol) were dissolved in anhydrous DCM (15 mL), and the resulting solution stirred at room temperature under an atmosphere of argon. A solution of N-acetyl-L-cysteine methyl ester 27 (0.15 g, 0.847 mmol) in a mixture of anhydrous DCM (15 mL) and anhydrous methanol (12 mL) was added slowly to the above solution. After a 2 h period, t.l.c. (petrol:ethyl acetate, 1:1) indicated the formation of a product (Rf 0.2) along with complete consumption of the starting material (Rf 0.1). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (petrol:ethyl acetate, 1:1) to afford N-acetyl-L-cysteine (2,3,4,6-tetra-O-benzyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 3 (0.52 g, 89%) as a white crystalline solid; m.p. 108–110 ºC (ethyl acetate/petrol); [α]D23 +35.2 (c, 1 in CHCl3); υmax (KBr disc) 3330 (br, NH) 1740 (s, C=O) 1651 (s, C=O) cm⁻¹; δH (400 MHz, CDCl3) 1.99 (3H, s, HNC(O)CH₃), 3.24 (1H, dd, JCH₂H 13.9 Hz, JCH₃,H 7.7 Hz, CH₃H'), 3.45 (1H, dd, JCH₂H 13.9 Hz, JCH₃,H 3.9 Hz, CH₃H'), 3.54 (1H, m, H-5), 3.68 (1H, at, J₃,₂ 9.1 Hz, J₂,₃ 9.0 Hz, H-2), 3.69-3.72 (2H, m, H-3, H-4), 3.74 (3H, s, OCH₃), 3.77 (1H, dd, J₆,₅ 1.9 Hz, J₅,₆' 11.4 Hz, H₆), 3.80 (1H, dd, J₆,₆' 3.8 Hz, J₅,₆' 11.4 Hz, H₆'), 4.48 (1H, d, J₃,₂ 9.1 Hz, H-1), 4.52-4.93 (8H, m, 4 x OCH₂Ph), 4.77 (1H, d, J₇,7 Hz, αH), 6.86 (1H, d, JNH₆,H 8.0 Hz, HNC(O)CH₃), 7.13-7.16 (2H, m, Ar-H), 7.27-7.35 (18H, m, Ar-H); δC (100.7 MHz, CDCl3) 23.0 (q, HNC(O)CH₃), 41.4 (t, CH₃H'), 52.3 (d, αC), 52.6 (q, OCH₃), 68.7 (t, C-6), 73.5, 75.1, 75.5, 75.7 (4 x t, 4 x OCH₂Ph), 78.9, 79.5 (3 x d, C-2, C-4, C-5), 86.4 (d, C-3), 89.9 (d, C-1), 127.7, 127.8, 127.9, 128.0, 128.1, 128.3, 128.4, 128.5, 128.6 (9 x d, 20 x Ar-C), 137.5, 137.6, 137.8, 138.2 (4 x s, 4 x Ar-C), 170.2, 171.0 (2 x s, COOCH₃, HNCOCH₃); m/z (ES⁺) 790 (MMeCNNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C₄₀H₄₅N₃O₈S₂ (MNa⁺) 754.2479. Found: 754.2479.; Found: C, 64.78%; H, 6.30%, N, 1.75%. C₄₀H₄₅N₃O₈S₂ requires: C, 64.64%; H, 6.20%; N, 1.91%.
Synthesis of \textit{N}-Acetyl-L-cysteine (2,3,4-tri-O-benzyl-1-dithio-\textalpha-L-fucopyranosyl disulfide) methyl ester 5

\begin{align*}
\text{L-Fucose} \; 33 & \quad (2.0 \; \text{g, 12.2 mmol}) \text{ was dissolved in pyridine (25 mL) under an atmosphere of argon. Acetic anhydride (25 mL) was added portionwise over 30 min and the mixture was left to stir at room temperature. After 16 h, t.l.c. (petrol:ethyl acetate, 1:1) indicated the formation of a product (Rf 0.4) with complete consumption of starting material (Rf 0). The reaction mixture was co-evaporated with toluene until no pyridine or acetic anhydride remained. The residue was recrystallised (diethyl ether/petrol) to afford 1,2,3,4-tetra-O-acetyl-\textalpha-L-fucopyranoside} \; 34 \quad (3.3 \; \text{g, 81\%}) \text{ as a white crystalline solid; m.p. 94-96 °C (diethyl ether/petrol) [Lit. 93 °C (diethyl ether/petrol)\textsuperscript{9}]; } [\alpha]_D^{21} \; -105.7 (c, 1 \text{ in CHCl}_3) \text{ [Lit. } [\alpha]_D^{14} \; -129.9 (c, 2 \text{ in acetone})\textsuperscript{9}]; \delta_H (400 \text{ MHz, CDCl}_3) \; 1.16 (3H, d, J \; 6.5 \text{ Hz, CH}_3), 2.00, 2.01, 2.14, 2.17 (12H, 4 \times s, 4 \times C(O)CH_3), 4.27 (1H, q, J \; 6.5 \text{ Hz, H-5}), 5.29-5.37 (3H, m, H-2, H-3, H-4), 6.34 (1H, d, J_{1,2} \; 2.7 \text{ Hz, H-1}); m/z (ES\textsuperscript{+}) \; 391 \text{ (MMeCNNH}_4^+, 100\%).
\end{align*}

Phenyl 2,3,4-tri-O-acetyl-1-thio-L-fucopyranoside\textsuperscript{10} 35

\begin{align*}
\text{1,2,3,4-Tetra-O-acetyl-\textalpha-L-fucopyranoside} \; 34 \quad (1.91 \; \text{g, 5.74 mmol}) \text{ was dissolved in anhydrous DCM (12 mL) under argon. Thiophenol (1.2 mL, 11.49 mmol) and boron trifluoride diethyl etherate (1.7 mL, 14.37 mmol) were added and the mixture was left to}
\end{align*}
stir at room temperature. After 16 h, t.l.c. (petrol:ethyl acetate, 3:1) indicated the
formation of a major product (Rf 0.6) and the complete consumption of starting material
(Rf 0.1). Triethylamine was added dropwise until the effervescence ceased. The
reaction mixture was diluted with DCM (40 mL), washed with sodium hydrogen
carbonate (2 x 30 mL of a saturated aqueous solution), water (30 mL) and brine
(30 mL), dried (MgSO4), filtered and concentrated in vacuo. The residue was purified by
flash column chromatography (petrol:ethyl acetate, 2:1) to give phenyl 2,3,4-tri-O-
acetyl-1-thio-L-fucopyranoside 35 (2.10 g, 96%) as a colourless oil; δH (400 MHz,
CDCl3) 1.14 (3H, d, J 6.5 Hz, CH3α), 1.25 (3H, d, J 6.4 Hz, CH3β), 1.98, 2.09, 2.15 (9H,
3 x s, 3 x C(O)CH3β), 2.02, 2.05, 2.17 (9H, 3 x s, 3 x C(O)CH3α), 3.84 (1H, q, J 6.4 Hz,
H-5β), 4.62 (1H, q, J 6.5 Hz, H-5α), 4.71 (1H, d, J1,2 9.9 Hz, H-1β), 5.06 (1H, dd,
J2,3 9.9 Hz, J3,4 3.4 Hz, H-3β), 5.23 (1H, at, J 9.9 Hz, H-2β), 5.27 (1H, br d, J 3.4 Hz,
H-4β), 5.30-5.37 (3H, m, H-2α, H-3α, H-4α), 5.94 (1H, d, J1,2 5.2 Hz, H-1α), 7.27-7.53
(10H, m, 5 x Ar-Hα, 5 x Ar-Hβ).

**Phenyl 2,3,4-Tri-O-benzyl-1-thio-L-fucopyranoside**11 36

![Phenyl 2,3,4-Tri-O-benzyl-1-thio-L-fucopyranoside](image)

A solution of phenyl 2,3,4-tri-O-acetyl-1-thio-L-fucopyranoside 35 (2.01 g, 5.27 mmol) in
anhydrous methanol (12 mL) was treated with sodium methoxide (57 mg, 1.05 mmol).
The mixture was stirred under an atmosphere of argon for 10 min, when t.l.c.
(petrol:ethyl acetate, 1:1) indicated formation of a single product (Rf 0) and complete
consumption of starting material (Rf 0.5). The reaction mixture was then concentrated
in vacuo. The resulting residue was dissolved in anhydrous DMF (20 mL), and sodium
hydride (60% dispersed in mineral oil) (1.82 g, 45.50 mmol) was added portionwise for
a period of 10 min at 0 °C. Benzyl bromide (3.8 mL, 31.62 mmol) was then added
dropwise and the mixture left to stir under an atmosphere of argon at RT. After a 16 h
period, t.l.c. (petrol:ethyl acetate, 7:3) indicated the formation of a major product
(Rf 0.5) with complete consumption of the starting material (Rf 0). The reaction mixture
was quenched by the slow addition of methanol (8 mL) and stirred for 10 min. The
resulting solution was diluted with water (15 mL) and extracted with ether (3 x 20 mL).
The organic layers were combined and washed with sodium hydrogen carbonate
(40 mL of a saturated aqueous solution), and water (40 mL), dried (MgSO4), filtered
and concentrated in vacuo. The residue was purified by flash column chromatography
(petrol:ethyl acetate, 6:1) to afford phenyl 2,3,4-tri-O-benzyl-1-thio-L-fucopyranoside 36 (2.79 g) being a mixture of anomers (α:β, 3:2) in quantitative yield over two steps; α anomer: \( \delta \)H (400 MHz, CDCl\(_3\)) 1.13 (3H, d, \( J \) 6.5 Hz, CH\(_3\)), 3.71 (1H, br d, \( J \) 2.3 Hz, H-4), 3.84 (1H, dd, \( J_{2,3} \) 10.0 Hz, \( J_{3,4} \) 2.9 Hz, H-3), 4.34 (1H, q, \( J \) 6.5 Hz, H-5), 4.38 (1H, dd, \( J_{1,2} \) 5.5 Hz, \( J_{2,3} \) 10.1 Hz, H-2), 4.66-5.05 (6H, m, 3 x OCH\(_2\)Ph), 5.74 (1H, d, \( J_{1,2} \) 5.5 Hz, H-1), 7.21-7.62 (20H, m, Ar-H); β anomer: \( \delta \)H (400 MHz, CDCl\(_3\)) 1.29 (3H, d, \( J \) 6.4 Hz, CH\(_3\)), 3.55 (1H, q, \( J \) 6.4 Hz, H-5), 3.62 (1H, dd, \( J_{2,3} \) 9.1 Hz, \( J_{3,4} \) 2.8 Hz, H-3), 3.66 (1H, br d, \( J \) 2.7 Hz, H-4), 3.95 (1H, at, \( J \) 9.4 Hz, H-2), 4.62 (1H, d, \( J_{1,2} \) 9.7 Hz, H-1), 4.66-5.05 (6H, m, 3 x OCH\(_2\)Ph), 7.21-7.62 (20H, m, Ar-H); m/z (ES\(^+\)) 585 (MMeCNNH\(_4^+\), 100%); HRMS (ES\(^+\)) Calcd. for C\(_{33}\)H\(_{34}\)NaO\(_4\)S (MNa\(^+\)) 549.2070. Found: 549.2060.

2,3,4-Tri-O-benzyl-α-L-fucopyranosyl phenylthiosulfonate 38

Bromine (38 µL, 0.799 mmol) was added to a solution of phenyl 2,3,4-tri-O-benzyl-1-thio-L-fucopyranoside 36 (363 mg, 0.699 mmol) in anhydrous DCM (3 mL), and after stirring for 1 h at room temperature cyclohexane (100 µL) was added. The resulting glycosyl bromide solution 37 was added dropwise to a solution of sodium phenylthiosulfonate 26 (315 mg, 1.605 mmol) and tetrabutylammonium bromide (23 mg, 0.069 mmol) in anhydrous acetonitrile (6 mL). The resulting mixture heated to 50 ºC and stirred under an atmosphere of argon. After 4 h, t.l.c. (petrol:ethyl acetate, 3:1) indicated the formation of a major product (R\(_f\) 0.3). The reaction mixture was diluted with DCM (20 mL), washed with brine (15 mL) and the aqueous layer re-extracted with DCM (2 x 20 mL). The organic layers were combined and washed with water (50 mL), dried (MgSO\(_4\)), filtered and concentrated \textit{in vacuo}. The residue was purified by flash column chromatography (petrol:ethyl acetate, 8:1) to afford 2,3,4-tri-O-benzyl-α-L-fucopyranosyl phenylthiosulfonate 38 (155 mg, 38% yield over two steps) as a colourless oil; \([\alpha]_D^{18}\) -35.1 (c, 1 in CHCl\(_3\)); \( \upsilon \)\textsubscript{max} (thin film) 1325 (s, SO\(_2\)) cm\(^{-1}\); \( \delta \)H (400 MHz, CDCl\(_3\)) 0.66 (3H, d, \( J \) 6.4 Hz, CH\(_3\)), 3.45 (1H, dd, \( J_{2,3} \) 10.0 Hz, \( J_{3,4} \) 2.8 Hz, H-3), 3.53 (1H, br d, \( J \) 2.0 Hz, H-4), 3.67 (1H, q, \( J \) 6.4 Hz, H-5), 4.32 (1H, dd, \( J_{1,2} \) 5.5 Hz, \( J_{2,3} \) 10.0 Hz, H-2), 4.57-4.94 (6H, m, 3 x OCH\(_2\)Ph), 6.20 (1H, d, \( J_{1,2} \) 5.5 Hz, H-1), 7.27-7.37 (15H, m, Ar-H), 7.47-7.60 (3H, m, Ar-H), 7.93-7.96 (2H, m, Ar-H); \( \delta \)C (100.7 MHz, CDCl\(_3\)) 15.8 (q, CH\(_3\)), 69.3 (d, C-5), 72.5, 73.5, 75.0 (3 x t, m; C-1, C-2, C-3).
3 x OCH₂Ph), 75.5 (d, C-2), 76.9 (d, C-4), 79.9 (d, C-3), 90.9 (d, C-1), 127.3, 127.5, 127.7, 127.8, 127.9, 128.0, 128.2, 128.5, 128.9 (9 x d, 16 x Ar-C), 133.4, 137.3, 138.1, 138.3 (4 x s, 4 x Ar-C); m/z (ES⁺) 649 (MMeCNNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C₃₃H₃₄NaO₆S₂ (MNa⁺) 613.1689. Found: 613.1692.

**N-Acetyl-l-cysteine (2,3,4-tri-O-benzyl-1-dithio-α-L-fucopyranosyl disulfide) methyl ester 5**

A solution of 2,3,4-tri-O-benzyl-1-thio-α-L-fucopyranosyl phenylthiosulfonate 38 (148 mg, 0.251 mmol) and triethylamine (12 µL, 0.084 mmol) were dissolved in anhydrous DCM (3 mL), and the resulting solution stirred at room temperature under an atmosphere of argon. A solution of N-acetyl-l-cysteine methyl ester 27 (16 mg, 0.084 mmol) in a mixture of anhydrous DCM (3 mL) and anhydrous methanol (2 mL) was slowly added via a syringe pump over a 2 h period. After 2 h, t.l.c. (petrol:ethyl acetate, 3:7) indicated the formation of a product (Rₚ 0.4) along with complete consumption of the starting material (Rₚ 0.1). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (petrol:ethyl acetate, 4:6) to afford N-acetyl-l-cysteine (2,3,4-tri-O-benzyl-1-dithio-α-L-fucopyranosyl disulfide) methyl ester 5 (48 mg, 31%) as white foam; [α]D₂⁵ -37.3 (c, 0.5 in CHCl₃); δmax (KBr disc) 3299 (br, NH) 1746 (s, C=O) 1654 (s, C=O) cm⁻¹; δH (500 MHz, CDCl₃) 1.17 (1H, d, J 6.4 Hz, CH₃), 2.03 (3H, s, HNC(O)C₃H₃), 3.34 (1H, dd, J₁,₂ 14.5 Hz, J₂,₃,₄ 5.0 Hz, CH₃,₄), 3.41 (1H, dd, J₁,₂ 14.5 Hz, J₂,₃,₄ 4.5 Hz, CH₃,₄), 3.71 (1H, br s, H-4), 3.73-3.75 (1H, m, H-3), 3.76 (3H, s, OCH₃), 4.06 (1H, q, J 6.5 Hz, H-5), 4.35 (1H, dd, J₁,₂ 5.4 Hz, J₂,₃ 9.6 Hz, H-2), 4.66-5.00 (6H, m, 3 x OCH₂Ph), 4.93-4.96 (1H, m, αH), 5.63 (1H, d, J₁,₂ 5.5 Hz, H-1), 6.36 (1H, br d, J₁,₂ 7.7 Hz, HNC(O)CH₃), 7.29-7.39 (15H, m, Ar-H); δC (125.8 MHz, CDCl₃) 16.3 (q, CH₃), 23.2 (q, HNC(O)CH₃), 41.3 (t, CH₂,₄H'), 51.8 (d, αC), 52.8 (q, OCH₃), 68.5 (d, C-5), 72.7, 73.3, 74.9 (3 x t, 3 x OCH₂Ph), 76.5 (d, C-2), 77.6 (d, C-4), 79.6 (d, C-3), 90.2 (d, C-1), 127.4, 127.6, 127.7, 127.8, 127.9, 128.2, 128.3, 128.4, 128.5 (9 x d, 15 x Ar-C), 137.7, 138.3, 138.5 (3 x s, 3 x Ar-C), 169.7, 170.8 (2 x s, COOCH₃, HNCOCH₃); m/z (ES⁺) 684 (MMeCNNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C₃₃H₃₉NaO₆S₂ (MNa⁺) 648.2060. Found: 648.2067.
Synthesis of \(\text{N-Acetyl-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-\(\beta\)-d-glucopyranosyl disulfide) methyl ester 7}\)

\[
\begin{align*}
\text{39} & \xrightarrow{\text{AcO}_2, \text{pyr}} \text{84\%} \quad \text{40} \\
\text{40} & \xrightarrow{\text{HBr (33\% in AcOH)}} \text{83\%} \quad \text{41} \\
\text{NaPTS 26} & \xrightarrow{\text{acetonitrile, 70 \degree C}} \text{70\%} \quad \text{42}
\end{align*}
\]

**Scheme S10.**

1,2,3,4,6-Penta-O-acetyl-D-glucopyranoside\(^{12,13}\) 40

\(\text{D-Glucose 39 (50.0 g, 278 mmol) was dissolved in pyridine (200 mL) under an atmosphere of argon. Acetic anhydride (250 mL) was added portionwise over 30 min and the mixture was left to stir at room temperature. After 22 h, t.l.c. (petrol:ethyl acetate, 1:1) indicated the formation of a product (R}_{f} 0.6) with complete consumption of starting material (R}_{f} 0). The reaction mixture was co-evaporated with ethanol until no pyridine or acetic anhydride remained. The residue was recrystallised (ethanol) to afford 1,2,3,4,6-penta-O-acetyl-D-glucopyranoside 40 (90.5 g, 84\%) as a white crystalline solid being a mixture of anomers (\(\alpha:\beta\), 1:1.2); m.p. 98-100 \degree C (ethanol) [Lit. 100-102 \degree C]\(^{12}; [\alpha]_D^{21} +51.3\) (c, 1.01 in CHCl\(_3\)) [Lit. [\(\alpha]_D^{19} +54.5\) (c, 3.8 in CHCl\(_3\)]\(^{13}; \delta_H (400 MHz, CDCl\(_3\)) 2.02, 2.03, 2.09, 2.11, 2.18 (15H, 5 x s, 5 x C(O)CH\(_3\alpha\)), 2.02, 2.03, 2.09, 2.12, 2.18 (15H, 5 x s, 5 x C(O)CH\(_3\beta\)), 3.82-3.86 (1H, m, H-5\(\alpha\)), 4.08-4.14 (3H, m, H-5\(\alpha\), H-6\'\(\alpha\), H-6\'\(\beta\)), 4.25-4.31 (2H, m, H-6\(\alpha\), H-6\(\beta\)), 5.08-5.17 (4H, m, H-2\(\alpha\), H-4\(\alpha\), H-2\(\beta\), H-4\(\beta\)), 5.25 (1H, at, J 9.4 Hz, H-3\(\beta\)), 5.47 (1H, at, J 9.8 Hz, H-3\(\alpha\)), 5.72 (1H, d, J\(_{1,2}\) 8.3 Hz, H-1\(\beta\)), 6.33 (1H, d, J\(_{1,2}\) 3.6 Hz, H-1\(\alpha\)).
2,3,4,6-Tetra-O-acetyl-α-D-glucopyranosyl bromide\textsuperscript{14} 41

\[
\text{Ac} \quad \text{O} \quad \text{O} \quad \text{O} \quad \text{Br}
\]

1,2,3,4,6-Penta-O-acetyl-D-glucopyranoside 40 (20.0 g, 51.2 mmol) was dissolved in anhydrous DCM (200 mL) and to this hydrogen bromide (33% w/w in acetic acid, 150 mL) was added. The mixture was stirred under argon at room temperature. After a 2 h period, t.l.c. (petrol:ethyl acetate, 3:1) indicated the formation of a product (R\textsubscript{f} 0.4) with complete consumption of starting material (R\textsubscript{f} 0.1). Ice water (250 mL) was added and the mixture stirred for 10 min. The two phases were separated and the aqueous layer re-extracted with DCM (3 x 50 mL). The combined organic layers were washed with sodium hydrogen carbonate (saturated aqueous solution) until pH 8 was obtained. The combined organics were washed with brine (200 mL), dried (MgSO\textsubscript{4}), filtered and concentrated \textit{in vacuo}. Recrystallisation (ethyl acetate/petrol) afforded 2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl bromide 41 (17.5 g, 83%) as a white crystalline solid; m.p. 84-86 °C (ethyl acetate/petrol) [Lit. 89.5-90.5 °C]\textsuperscript{14}; [\alpha]_D\textsuperscript{22} +182.1 (c, 1.01 in CHCl\textsubscript{3}) [Lit. [\alpha]_D +186 (c, 6 in CH\textsubscript{2}Cl\textsubscript{2})]\textsuperscript{14}; \delta\textsubscript{H} (400 MHz, CDCl\textsubscript{3}) 2.04, 2.06, 2.10, 2.11 (12H, 4 x s, 4 x C(O)CH\textsubscript{3}), 4.14 (1H, dd, J\textsubscript{5,6} 1.9 Hz, J\textsubscript{6,6'} 12.6 Hz, H-6), 4.28-4.36 (2H, m, H-5, H-6'), 4.85 (1H, dd, J\textsubscript{1,2} 4.0 Hz, J\textsubscript{2,3} 10.0 Hz, H-2), 5.17 (1H, at, J 9.8 Hz, H-4), 5.56 (1H, at, J 9.7 Hz, H-3), 6.25 (1H, d, J\textsubscript{1,2} 4.0 Hz, H-1).

2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl phenylthiosulfonate\textsuperscript{2} 42

\[
\text{Ac} \quad \text{O} \quad \text{O} \quad \text{SSO}_2\text{Ph}
\]

2,3,4,6-Tetra-O-acetyl-α-D-glucopyranose bromide 41 (7.90 g, 19.21 mmol) was dissolved in anhydrous acetonitrile (80 mL). To this solution sodium phenylthiosulfonate (7.51 g, 38.42 mmol) and tetrabutylammonium bromide (0.62 g, 1.92 mmol) were added. The resulting mixture was stirred under argon at 70 °C. After a 4.5 h period, t.l.c. (petrol:ethyl acetate, 1:1) indicated the formation of a major product (R\textsubscript{f} 0.2) with complete consumption of the starting material (R\textsubscript{f} 0.3). The reaction mixture was concentrated \textit{in vacuo}. The crude solid was partitioned between DCM (100 mL) and water (80 mL), and the aqueous layer re-extracted with DCM (2 x 100 mL). The combined organic layers were washed with brine (80 mL), dried (MgSO\textsubscript{4}), filtered and concentrated \textit{in vacuo}. Recrystallisation (ethyl acetate/petrol) afforded 2,3,4,6-tetra-O-
acetyl-β-D-glucopyranosyl phenylthiosulfonate 42 (6.81 g, 70 %) as a white crystalline solid; m.p. 128-130 °C (ethyl acetate/petrol) [Lit. 129-130 °C (ethyl acetate/petrol)]\(^2\); [α]\(D\)\(^23\) +48.3 (c, 1 in CHCl\(_3\)) [Lit. [α]\(D\)\(^25\) +51.2 (c, 1 in CHCl\(_3\))]\(^2\); δ\(_H\) (400 MHz, CDC\(_3\)) 1.99, 2.00, 2.02, 2.05 (12H, 4 x s, 4 x C(O)CH\(_3\)), 3.74 (1H, ddd, J\(_{4,5}\) 10.1 Hz, J\(_{5,6}\) 2.3 Hz, J\(_{5,6}^\prime\) 4.3 Hz, H-5), 3.91 (1H, dd, J\(_{5,6}\) 2.3 Hz, J\(_{6,6}^\prime\) 12.5 Hz, H-6), 4.11 (1H, dd, J\(_{5,6}\) 4.3 Hz, J\(_{6,6}^\prime\) 12.5 Hz, H-6'), 4.99-5.05 (2H, m, H-2, H-4), 5.26 (1H, d, J\(_{1,2}\) 10.4 Hz, H-1), 5.27 (1H, at, J 9.3 Hz, H-3), 7.53-7.67 (3H, m, Ar-H), 7.93-7.95 (2H, m, Ar-H).

**N-Acetyl-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 7**

2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl phenylthiosulfonate 42 (200 mg, 0.397 mmol) was dissolved in anhydrous DCM (8 mL) and stirred at room temperature under an atmosphere of argon. A solution of N-acetyl-L-cysteine methyl ester 27 (70 mg, 0.397 mmol) and triethylamine (55 µL, 0.397 mmol) in a mixture of anhydrous DCM (15 mL) and anhydrous methanol (2 mL) was slowly added via a syringe pump over a 2 h period. After 2 h, t.l.c. (ethyl acetate) indicated the formation of a product (R\(_f\) 0.4) along with complete consumption of the starting material (R\(_f\) 0.3). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (ethyl acetate) to afford N-acetyl-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 7 (164 mg, 76%) as a white amorphous solid; [α]\(D\)\(^18\) +19.8 (c, 1 in CHCl\(_3\)); \(\nu\)\(_{\text{max}}\) (KBr disc) 3290 (br, NH) 1749 (s, C=O) 1663 (s, C=O) cm\(^{-1}\); δ\(_H\) (400 MHz, CDC\(_3\)) 2.00, 2.02, 2.03, 2.04, 2.08 (15H, 5 x s, 4 x C(O)CH\(_3\), HNC(O)CH\(_3\)), 3.09 (1H, dd, J\(_{\text{CH}_{2}H}\) 14.2 Hz, J\(_{\text{CH}_{2}H_{\alpha}}\) 6.8 Hz, CH\(_{1}\)H'), 3.33 (1H, dd, J\(_{\text{CH}_{2}H'}\) 14.2 Hz, J\(_{\text{CH}_{2}H_{\alpha}'}\) 4.4 Hz, CH\(_{1}\)H'), 3.77 (3H, s, OCH\(_3\)), 3.81-3.85 (1H, m, H-5), 4.18 (1H, dd, J\(_{5,6}\) 2.2 Hz, J\(_{6,6}^\prime\) 12.5 Hz, H-6), 4.27 (1H, dd, J\(_{5,6}\) 4.7 Hz, J\(_{6,6}^\prime\) 12.5 Hz, H-6'), 4.59 (1H, d, J\(_{1,2}\) 9.5 Hz, H-1), 4.99-4.99 (1H, m, aH), 5.10 (1H, at, J 9.7 Hz, H-4), 5.21 (1H, at, J 9.4 Hz, H-2), 5.25 (1H, at, J 9.2 Hz, H-3), 6.41 (1H, d, J\(_{\text{NH}_{1,\alpha}}\) 8.0 Hz, HNC(O)CH\(_3\)); δ\(_C\) (100.7 MHz, CDC\(_3\)) 20.6, 20.7, 20.8 (3 x q, 4 x C(O)CH\(_3\)), 23.1 (q, HNC(O)CH\(_3\)), 41.9 (t, CH\(_{1}\)H'), 51.9 (d, αC), 52.8 (q, OCH\(_3\)), 61.9 (t, C-6), 67.9 (d, C-4), 68.9 (d, C-2), 73.7 (d, C-3), 76.1 (d, C-5), 88.9 (d, C-1), 169.4,
169.8, 170.1, 170.6, 171.0, 172.4 (6 x s, 4 x C(O)CH₃, HNC(O)CH₃, CO₂CH₃); m/z (ES⁺) 598 (MMeCNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C₂₀H₂₉NNaO₁₂S₂ (MNa⁺) 562.1017. Found: 562.1023; Found: C, 44.43%; H, 5.49%, N, 2.58%. C₄₀H₄₅NO₈S₂ requires: C, 44.52%; H, 5.42%; N, 2.60%.

Synthesis of N-Acetyl-L-cysteinamide

N-acetyl-L-cysteine methyl ester (387 mg, 2.19 mmol) was stirred in a 1:1 mixture of toluene and ammonium hydroxide. After 19 h, t.l.c. (ethyl acetate) showed comsumption of starting material (R₁ 0.3) and formation of a product (R₁ 0). The reaction mixture was concentrated in vacuo at 60 °C and the resulting residue purified by recrystallisation (ethanol) to afford N-acetyl-L-cysteinamide (322 mg, 91%) as a white crystalline solid; m.p. 147-149 °C (ethanol) [Lit. 148-150 °C (ethanol)]; [α]₀ ₂₅ -44.0 (c, 1 in H₂O) [Lit. [α]₀ ₂₅ -12.28 (c, 5 in H₂O)]; δH (400 MHz, CDCl₃) 2.03 (3H, s, HNC(O)CH₃), 2.80 (1H, dd, JCH,H' 13.9 Hz, JCH₂H 7.3 Hz, CH₂H'), 2.92 (1H, dd, JCH,H' 13.9 Hz, JCH₂H 9.2 Hz, CH₂H'), 4.72 (1H, dd, J 4.9 Hz, J 9.2 Hz, αH); δC (100.7 MHz, CDCl₃) 21.5 (q, HNC(O)CH₃), 25.9 (t, CH₂H'), 55.8 (d, αC), 172.4 (s, HNC(O)CH₃), 174.2 (s, C(O)NH₂); m/z (ES⁺) 161 (M-H⁺, 100%).

Synthesis of N-Acetyl-L-cysteinamide (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-glucopyranosyl disulfide) 9

Scheme S11.
N-Acetyl-L-cysteinamide (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-glucopyranosyl disulfide) 9

\[ \text{AcO} \quad \begin{array}{c} \text{O} \\ \text{Ac} \quad \text{S} \quad \text{S} \quad \text{AcH}\text{N} \quad \text{NH} \end{array} \]

2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl phenylthiosulfonate 42 (407 mg, 0.807 mmol) was dissolved in anhydrous DCM (8 mL) and stirred at room temperature under an atmosphere of argon. A solution of N-acetyl-L-cysteinamide 43 (131 mg, 0.807 mmol) and triethylamine (0.11 mL, 0.807 mmol) in a mixture of anhydrous DCM (10 mL) and anhydrous methanol (8 mL) was slowly added via a syringe pump over a 2 h period. After 3 h, t.l.c. (ethyl acetate:MeOH, 9:1) indicated the formation of a product (Rf 0.4) along with complete consumption of the starting material (Rf 0.3). The reaction mixture was concentrated \textit{in vacuo} and the resulting residue purified by recrystallisation (ethyl acetate) to afford N-acetyl-L-cysteinamide (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-glucopyranosyl disulfide) 9 (260 mg, 61%) as a white amorphous solid; [α]D\textsubscript{25} \text{−} 173 (c, 1 in MeOH); \( \nu \)\text{max} (KBr disc) 3046 (br, NH NH\textsubscript{2}) 1748 (s, C=O) 1638 (s, C=O) cm\textsuperscript{−1}; \( \delta \)\text{H} (400 MHz, CD\textsubscript{3}OD) 1.99, 2.03, 2.07 (15H, 3 x s, 4 x C(O)CH\textsubscript{3}, HNC(O)CH\textsubscript{3}), 2.97 (1H, dd, J_{CH,H} \text{ H} 13.8 Hz, J_{CH,\text{H'}} \text{ H} 9.7 Hz, CH, H'), 3.36 (1H, dd, J_{CH,\text{H'}} \text{ H} 13.9 Hz, J_{CH,\text{H''}} \text{ H} 4.6 Hz, CH', H'), 3.97 (1H, ddd, J_{CH',H} \text{ H} 10.2 Hz, J_{5,6} \text{ H} 2.3 Hz, J_{5,6'} \text{ H} 4.3 Hz, H-5), 4.33 (1H, dd, J_{5,6} \text{ H} 2.2 Hz, J_{6,6'} \text{ H} 12.5 Hz, H-6), 4.38 (1H, dd, J_{5,6} \text{ H} 4.4 Hz, J_{6,6'} \text{ H} 12.5 Hz, H-6'), 4.75-4.78 (1H, m, \alpha H), 4.79 (1H, d, J_{1,2} \text{ H} 9.5 Hz, H-1), 5.07 (1H, at, J 9.7 Hz, H-4), 5.27 (1H, at, J 9.4 Hz, H-2), 5.34 (1H, at, J 9.3 Hz, H-3); \( \delta \)\text{C} (100.7 MHz, CD\textsubscript{3}OD) 19.5, 19.6, 19.7, 19.8 (4 x q, 4 x C(O)CH\textsubscript{3}), 21.6 (q, HNC(O)CH\textsubscript{3}), 41.8 (t, CH, H'), 52.5 (d, \alpha C), 62.1 (t, C-6), 68.3 (d, C-4), 69.4 (d, C-2), 74.2 (d, C-3), 76.0 (d, C-5), 87.4 (d, C-1), 169.9, 170.1, 170.5, 171.4, 172.5 (5 x s, 4 x C(O)CH\textsubscript{3}, HNC(O)CH\textsubscript{3}), 174.1 (s, CONH\textsubscript{2}); m/z (ES\textsuperscript{+}) 547 (MNa\textsuperscript{+}, 100%) 583 (MMeCNNH\textsubscript{4}\textsuperscript{+}, 70%); HRMS (ES\textsuperscript{+}) Calcd. for C\textsubscript{19}H\textsubscript{28}N\textsubscript{2}NaO\textsubscript{11}S\textsubscript{2} (MNa\textsuperscript{+}) 547.1027. Found: 547.1027; Found: C, 44.85%; H, 5.73%, N, 5.34%. C\textsubscript{19}H\textsubscript{28}N\textsubscript{2}O\textsubscript{11}S\textsubscript{2} requires: C, 44.50%; H, 5.38%; N, 5.34%. 
Synthesis of \(N\)-Acetyl-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-\(\beta\)-D-galactopyranosyl disulfide) methyl ester 11

Scheme S12.

1,2,3,4,6-Penta-O-acetyl-\(\alpha\)-D-galactopyranoside\(^{16}\) 45

A solution of D-galactose 44 (30.0 g, 167 mmol) in pyridine (200 mL) was treated with acetic anhydride (250 mL), and stirred at room temperature under an atmosphere of argon. After 24 h, t.l.c. (petrol:ethyl acetate, 1:1) indicated the formation of a product (\(R_f\) 0.5) with complete consumption of starting material (\(R_f\) 0). The reaction mixture was co-evaporated with ethanol until no pyridine or acetic anhydride remained. The residue was recrystallised (ethanol) to afford 1,2,3,4,6-penta-O-acetyl-\(\alpha\)-D-galactopyranoside 45 (82.3 g, 74%) as white crystalline solid; m.p. 88-90 ºC (ethanol) [Lit. 92-94 ºC\(^{16}\); \(\left[\alpha\right]_D^{21}\) +87.7 (c, 1.06 in CHCl\(_3\)) [Lit. \(\left[\alpha\right]_D^{25}\) +107 (c, 1.0 in CHCl\(_3\))\(^{16}\); \(\delta_H\) (400 MHz, CDCl\(_3\)) 2.00, 2.02, 2.04, 2.16 (15H, 4 x s, 5 x C(O)CH\(_3\)), 4.08 (1H, dd, \(J_{5,6}\) 6.7 Hz, \(J_{6,6}'\) 11.3 Hz, H-6), 4.12 (1H, dd, \(J_{5,6}\) 6.7 Hz, H-6'), 4.34 (1H, dt, \(J_{d,6}\) 0.6 Hz, H-5), 5.33 (2H, at, \(J_{1.3}\) Hz, \(J_{1.7}\) Hz, H-2, H-4), 5.50 (1H, br s, H-3), 6.38 (1H, d, \(J_{1.2}\) 1.6 Hz, H-1).

2,3,4,6-Tetra-O-acetyl-\(\alpha\)-D-galactopyranosyl bromide\(^{17}\) 46

1,2,3,4,6-Penta-O-acetyl-\(\alpha\)-D-galactopyranoside 45 (1.0 g, 2.56 mmol) was dissolved in anhydrous DCM (10 mL) and to this hydrogen bromide (33% w/w in acetic acid, 10 mL)
was added. The mixture was stirred under argon at room temperature. After a 18 h period, t.l.c. (petrol:ethyl acetate, 3:1) indicated the formation of a product (R<sub>f</sub> 0.3) with complete consumption of starting material (R<sub>f</sub> 0.2). Ice water (15 mL) was added and the mixture stirred for 10 min. The two phases were separated and the aqueous layer re-extracted with DCM (3 x 10 mL). The combined organic layers were washed with sodium hydrogen carbonate (saturated aqueous solution) until pH 8 was obtained. The combined organics were washed with brine (20 mL), dried (MgSO<sub>4</sub>), filtered and concentrated in vacuo. Recrystallisation (diethyl ether/petrol) afforded 2,3,4,6-tetra-O-acetyl-α-D-galactopyranosyl bromide 46 (1.0 g, 95%) as a white crystalline solid; m.p. 84-86 °C (diethyl ether/petrol) [Lit. 84-85 °C]<sup>17</sup>; [α]<sub>D</sub><sup>21</sup> +212 (c, 1 in CHCl<sub>3</sub>); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) 2.02, 2.06, 2.12, 2.16 (12H, 4 x s, 4 x C(O)CH<sub>3</sub>), 4.09-4.21 (2H, m, H-6, H-6'), 4.49 (1H, at, J 6.6 Hz, H-5), 5.05 (1H, dd, J<sub>1,2</sub> 3.9 Hz, J<sub>2,3</sub> 10.6 Hz, H-2), 5.41 (1H, dd, J<sub>2,3</sub> 10.6 Hz, J<sub>3,4</sub> 3.3 Hz, H-3), 5.53 (1H, br d, J 3.3 Hz, H-4), 6.76 (1H, d, J<sub>1,2</sub> 3.9 Hz, H-1).

2,3,4,6-Tetra-O-acetyl-β-D-galactopyranosyl phenylthiosulfonate<sup>2</sup> 47

2,3,4,6-Tetra-O-acetyl-α-D-galactopyranosyl bromide 46 (1.0 g, 2.43 mmol) was dissolved in anhydrous acetonitrile (40 mL). To this solution sodium phenylthiosulfonate 26 (0.95 g, 4.86 mmol) and tetrabutylammonium bromide (78 mg, 0.243 mmol) were added. The resulting mixture was stirred under argon at 70 °C. After a 5 h period, t.l.c. (petrol:ethyl acetate, 1:1) indicated the formation of a major product (R<sub>f</sub> 0.4) with complete consumption of the starting material (R<sub>f</sub> 0.6). The reaction mixture was concentrated in vacuo. The crude solid was partitioned between DCM (50 mL) and water (30 mL), and the aqueous layer re-extracted with DCM (2 x 50 mL). The combined organic layers were washed with brine (80 mL), dried (MgSO<sub>4</sub>), filtered and concentrated in vacuo. The residue was purified by flash column chromatography (ethyl acetate:petrol, 2:1) afforded 2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl phenylthiosulfonate 47 (0.82 g, 67%) as a white crystalline solid; m.p. 56-58 °C [Lit. 53-54 °C]<sup>2</sup>; [α]<sub>D</sub><sup>21</sup> +21.2 (c, 1 in CHCl<sub>3</sub>); [α]<sub>D</sub><sup>27</sup> +24.2 (c, 1 in CHCl<sub>3</sub>); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) 1.98, 2.03, 2.06, 2.11 (12H, 4 x s, 4 x C(O)CH<sub>3</sub>), 3.85 (1H, dd, J<sub>5,6</sub> 8.8 Hz, J<sub>6,6</sub>' 13.6 Hz, H-6), 3.93-3.99 (2H, m, H-5, H-6'), 5.11 (1H, dd, J<sub>2,3</sub> 9.6 Hz,
\( J_{3,4} \) 3.3 Hz, H-3), 5.22 (1H, at, \( J \) 9.9 Hz, H-2), 5.28 (1H, d, \( J_{1,2} \) 9.9 Hz, H-1), 5.43 (1H, br d, \( J \) 3.3 Hz, H-4), 7.54-7.68 (3H, m, Ar-H), 7.94-7.97 (2H, m, Ar-H).

**N-Acetyl-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-galactopyranosyl disulfide) methyl ester 11**

![Chemical Structure of 11](attachment:structure.png)

2,3,4,6-Tetra-O-acetyl-β-D-galactopyranosyl phenylthiosulfonate 47 (339 mg, 0.672 mmol) was dissolved in anhydrous DCM (10 mL) and stirred at room temperature under an atmosphere of argon. A solution of \( N \)-acetyl-L-cysteine methyl ester 27 (119 mg, 0.672 mmol) and triethylamine (0.1 mL, 0.672 mmol) in a mixture of anhydrous DCM (10 mL) and anhydrous methanol (2 mL) was slowly added via a syringe pump over a 2 h period. After a 2 h period, t.l.c. (ethyl acetate) indicated the formation of a product (R\(_f\) 0.4). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (ethyl acetate) to afford \( N \)-acetyl-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-galactopyranosyl disulfide) methyl ester 11 (228 mg, 63%) as a white amorphous solid; \([\alpha]_D^{20} +27.3 \) (c, 1 in CHCl\(_3\)); \( \nu_{\text{max}} \) (KBr disc) 3373 (br, NH) 1665 (s, C=O) cm\(^{-1}\); \( \delta_H \) (400 MHz, CDCl\(_3\)) 1.99, 2.05, 2.06, 2.07, 2.17 (15H, 5 x s, 4 x C(O)CH\(_3\), HNC(O)CH\(_3\)), 3.13 (1H, dd, \( J_{\text{CH,H}',\alpha} \) 14.3 Hz, \( J_{\text{CH,H},\alpha} \) 14.2 Hz, \( J_{\text{CH,H},\alpha} \) 14.2 Hz, \( J_{\text{CH,H},\alpha} \) 14.3 Hz, \( J_{\text{CH,H},\alpha} \) 14.3 Hz, CH\(_3\)), 3.36 (1H, dd, \( J_{\text{CH,H}',\alpha} \) 14.3 Hz, \( J_{\text{CH,H},\alpha} \) 14.3 Hz, \( J_{\text{CH,H},\alpha} \) 14.3 Hz, CH\(_3\)), 3.79 (3H, s, OCH\(_3\)), 4.06-4.09 (1H, m, H-5), 4.11-4.17 (2H, m, H-6, H-6'), 4.62 (1H, d, \( J_{1,2} \) 9.9 Hz, H-1), 4.97-5.02 (1H, m, \( \alpha \)H), 5.09 (1H, dd, \( J_{2,3} \) 10.0 Hz, \( J_{3,4} \) 3.4 Hz, H-3), 5.36 (1H, at, \( J \) 9.9 Hz, H-2), 5.45 (1H, br d, \( J \) 3.3 Hz, H-4), 6.39 (1H, \( J_{\text{NH},\alpha} \) 8.0 Hz, HNC(O)CH\(_3\)); \( \delta_C \) (100.7 MHz, CDCl\(_3\)) 20.5, 20.6, 20.7, 20.8 (4 x q, 4 x C(O)CH\(_3\)), 23.2 (q, HNC(O)CH\(_3\)), 42.1 (t, CH\(_3\)), 52.0 (d, \( \alpha \)C), 52.8 (q, OCH\(_3\)), 61.5 (t, C-6), 66.6 (d, C-2), 67.2 (d, C-4), 71.7 (d, C-3), 74.9 (d, C-5), 90.3 (d, C-1), 169.5, 169.8, 170.0, 170.1, 170.4, 171.0 (6 x s, 4 x C(O)CH\(_3\), HNC(O)CH\(_3\), CO\(_2\)CH\(_3\)); \( m/z \) (ES\(^+\)) 598 (MMeCNNH\(_4^+\), 100%); HRMS (ES\(^+\)) Calcd. for C\(_{20}\)H\(_{29}\)NNaO\(_{12}\)S\(_2\) (MNa\(^+\)) 562.1023. Found: 562.1025.
Synthesis of \(N\)-Acetyl-L-cysteine \((3,4,6\text{-tetra-}O\text{-acetyl-}2\text{-acetamido-}2\text{-deoxy-1-dithio-}\beta\text{-d-glucopyranosyl disulfide}) \) methyl ester 13

Scheme S13.

3,4,6-Tri-\(O\)-acetyl-2-\(N\)-acylamido-2-deoxy-\(\alpha\)-d-glucopyranosyl chloride\(^{18,19}\) 49

Acetyl chloride (40 mL, 563 mmol) was added through an air condenser into a round bottom flask containing 2-acetamido-2-deoxy-\(d\)-glucose 48 (20.0 g, 90.41 mmol). The reaction mixture was heated for 1 h until a colour change was observed (pink) and the reaction mixture was stirred vigorously overnight. After 16 hours, t.l.c. (petrol:ethyl acetate, 1:2) indicated formation of a product \((R, 0.3)\) with complete consumption of the starting material \((R, 0)\). The reaction mixture was diluted with DCM (150 mL) and then poured on to ice water (100 mL). The organic layer was washed with ice cold sodium bicarbonate (3 x 100 mL) until no more gas was evolved. The organic layer was dried \((\text{MgSO}_4)\), filtered and concentrated \textit{in vacuo}. Recrystallization (diethyl ether/DCM) yielded 3,4,6-tri-\(O\)-acetyl-2-\(N\)-acylamido-2-deoxy-\(\alpha\)-d-glucopyranosyl chloride 49 as a crystalline solid (23.95 g, 72%); m.p. 120-122 °C (diethyl ether/DCM) \([\text{Lit. 122-123 °C}^{18}; [\alpha]_D^{26} +127.0 \text{ (c, 1 in CHCl}_3) [\text{Lit. [\alpha]_D}^{26} +120.6 \text{ (c, 1.03 in CHCl}_3)\])^{12}; \delta H (400 MHz, CDCl\textsubscript{3}) 1.99, 2.06, 2.11 (12H, 3 x s, 3 x C(O)CH\textsubscript{3}, HNC(O)CH\textsubscript{3}), 4.05-4.14 (1H, m, H-6), 4.23-4.31 (2H, m, H-5, H-6'), 4.53 (1H, ddd, \(J_{1,2} 3.7 \text{ Hz, J}_{2,3} 10.7 \text{ Hz, J}_{2,NH} 8.9 \text{ Hz, H-2})\), 5.22 (1H, at, \(J 9.8 \text{ Hz, H-4})\), 5.32 (1H, at, \(J 10.0 \text{ Hz, H-3})\), 5.83 (1H, d, \(J 8.6 \text{ Hz, HNC(O)CH_3})\), 6.19 (1H, d, \(J_{1,2} 3.7 \text{ Hz, H-1})\).
(3,4,6-Tri-O-acetyl-2-acetamido-2-deoxy-β-D-glucopyranosyl)-1-isothiouronium chloride³ 50

3,4,6-Tri-O-acetyl-2-acetamido-2-deoxy-α-D-glucopyranosyl chloride 49 (5.0 g, 13.67 mmol) and thiourea (1.8 g, 23.24 mmol) were dissolved in anhydrous acetone (40 mL). The reaction mixture was stirred under an atmosphere of argon and heated to 60 ºC. After a 2 h period a white solid precipitated. The precipitate was removed by filtration, the filtrate was returned to reflux, and this process was repeated until the solid ceased to precipitate. The off white crystals were combined and recrystallised from acetone/petrol to afford (3,4,6-tri-O-acetyl-2-acetamido-2-deoxy-β-D-glucopyranosyl)-1-isothiouronium chloride 50 (4.5 g, 75%) as a white crystalline solid; m.p. 134-136 ºC (acetone/petrol) [Lit. 134-137 ºC (acetone/petrol)]³; [α]D 20 -24.6 (c, 1 in H₂O) [Lit. [α]D 25 -25.2 (c, 1 in H₂O)]³; δH (400 MHz, DMSO-d₆) 1.80 (3H, s, HNC(O)CH₃), 1.94, 1.97, 2.01 (9H, 3 x s, 3 x C(O)CH₃), 4.00 (1H, at, J 9.9 Hz, H-2), 4.06 (1H, dd, J₅,₆ 2.0 Hz, J₆,₆' 11.4 Hz, H-6), 4.17 (1H, dd, J₅,₆ 4.8 Hz, J₆,₆' 11.4 Hz, H-6'), 4.22 (1H, ddd, J₄,₅ 9.9 Hz, J₆,₆ 2.0 Hz, J₆,₆' 4.8 Hz, H-5), 4.93 (1H, at, J 9.6 Hz, H-4), 5.13 (1H, at, J 9.8 Hz, H-3), 5.67 (1H, d, J₁,₂ 10.5 Hz, H-1), 8.43 (1H, d, J 9.3 Hz, NH), 9.20 (2H, br s, NH₂), 9.39 (2H, br s, NH₂); δC (100.7 MHz, DMSO-d₆) 21.1, 21.3, 21.4 (3 x q, 3 x C(O)CH₃), 23.4 (q, HNC(O)CH₃), 52.0 (d, C-2), 62.3 (t, C-6), 68.7 (d, C-4), 73.5 (d, C-3), 75.6 (d, C-5), 81.5 (d, C-1), 168.0 (s, C=O), 170.1, 170.5, 170.8, 170.9 (4 x s, 3 x C(O)CH₃, HNC(O)CH₃).

1-Thio-3,4,6-Tri-O-acetyl-2-acetamido-2-deoxy-β-D-glucopyranose³ 51

(3,4,6-Tri-O-acetyl-2-acetamido-2-deoxy-β-D-glucopyranosyl)-1-isothiuronium chloride 50 (4.4 g, 9.96 mmol) and sodium metabisulfite (2.3 g, 11.95 mmol) were dissolved in a mixture of DCM (60 mL) and water (30 mL). The mixture was heated to reflux under an atmosphere of argon. After a 2 h period the reaction was cooled to room temperature and the phases were separated. The aqueous layer was re-extracted with DCM (2 x 60 mL). The organics were combined and washed with water (60 mL) and brine (60 mL), dried (MgSO₄), filtered and concentrated in vacuo. Recrystallisation from
ethyl acetate/petrol afforded 1-thio-3,4,6-Tri-O-acetyl-2-acetamido-2-deoxy-β-d-glucopyranose 51 (2.7 g, 74%) as a white solid; m.p. 166-168 °C (ethyl acetate/petrol) [Lit. 165-187 °C (ethyl acetate/petrol)]\(^3\); \([\alpha]_D^{20}\) -25.3 (c, 1 in CHCl\(_3\)) [Lit. \([\alpha]_D^{25}\) -24.8 (c, 1 in CHCl\(_3\))]\(^3\); \(\delta_H\) (400 MHz, CDCl\(_3\)) 1.99, 2.03, 2.05, 2.10 (12H, 4 x s, 3 x C(O)CH\(_3\), HNC(O)CH\(_3\)), 2.57 (1H, d, \(J_{5,6}\) 9.4 Hz, SH), 3.69 (1H, ddd, \(J_{4,5}\) 9.5 Hz, \(J_{5,6}\) 2.2 Hz, \(J_{5,6}'\) 4.8 Hz, H-5), 4.00 (1H, at, \(J_9\) 9.9 Hz, H-2), 4.13 (1H, dd, \(J_{5,6}\) 2.3 Hz, \(J_{6,6}'\) 12.4 Hz, H-6), 4.24 (1H, dd, \(J_{5,6}'\) 4.8 Hz, \(J_{6,6}'\) 12.4 Hz, H-6'), 4.58 (1H, at, \(J_9\) 9.7 Hz, H-1), 5.08 (1H, at, \(J_9\) 9.4 Hz, H-3), 5.13 (1H, at, \(J_9\) 9.3 Hz, H-4), 5.70 (1H, d, \(J_9\) 9.5 Hz, HNC(O)CH\(_3\)); \(\delta_C\) (100.7 MHz, CDCl\(_3\)) 20.6, 20.7, 20.8 (3 x q, 3 x C(O)CH\(_3\)), 23.3 (q, HNC(O)CH\(_3\)), 56.8 (d, C-2), 62.1 (t, C-6), 68.0 (d, C-4), 73.5 (d, C-3), 76.3 (d, C-5), 80.4 (d, C-1), 169.2, 170.4, 170.8, 171.3 (4 x s, 3 x C(O)CH\(_3\), HNC(O)CH\(_3\)).

**Phenyl 3,4,6-tri-O-acetyl-2-acetamido-2-deoxy-1-selenenylsulfide-β-d-glucopyranoside\(^3\)** 52

1-Thio-3,4,6-tri-O-acetyl-2-acetamido-2-deoxy-β-d-glucopyranose 51 (406 mg, 1.11 mmol) and phenylselenyl bromide (395 mg, 1.67 mmol) were dissolved in anhydrous DCM (10 mL). The resulting mixture was stirred under an atmosphere of argon at room temperature. After 10 min, t.l.c. (ethyl acetate) indicated the formation of a major product (R\(_t\) 0.4). The reaction was quenched with the addition of triethylamine (2 mL) and stirred for 5 min. The mixture was portioned between DCM (10 mL) and water (15 mL), the aqueous phase was separated and re-extracted with DCM (2 x 20 mL). The combined organic layers were washed with brine (25 mL), dried (MgSO\(_4\)), filtered and concentrated in vacuo. The residue was purified by flash column chromatography (ethyl acetate) to afford phenyl 3,4,6-tri-O-acetyl-2-acetamido-2-deoxy-1-selenenylsulfide-β-d-glucopyranoside 52 (424 mg, 73 %) as a white crystalline solid; m.p. 176-178 °C [Lit. 177-179 °C]\(^3\); \([\alpha]_D^{20}\) -141.3 (c, 1 in CHCl\(_3\)) [Lit. \([\alpha]_D^{25}\) -134.0 (c, 1 in CHCl\(_3\))]\(^3\); \(\delta_H\) (400 MHz, CDCl\(_3\)) 1.89 (3H, s, HNC(O)CH\(_3\)), 2.01, 2.02, 2.04 (9H, 3 x s, 3 x C(O)CH\(_3\)), 3.75 (1H, ddd, \(J_{4,5}\) 10.0 Hz, \(J_{5,6}\) 2.3 Hz, \(J_{5,6}'\) 4.7 Hz, H-5), 4.08 (1H, dd, \(J_{5,6}\) 2.3 Hz, \(J_{6,6}'\) 12.3 Hz, H-6), 4.16 (1H, dd, \(J_{5,6}'\) 4.7 Hz, \(J_{6,6}'\) 12.3 Hz, H-6'), 4.20 (1H, at, \(J_{10}\) 10.3 Hz, H-2), 4.78 (1H, at, \(J_{10}\) 10.1 Hz, H-1), 5.11 (1H, at, \(J_{9}\) 9.7 Hz, H-4), 5.28 (1H, at, \(J_{9}\) 9.8 Hz, H-3), 5.46 (1H, d, \(J_{9}\) 9.0 Hz, HNC(O)CH\(_3\)), 7.26-7.29 (3H, m, Ar-H), 7.69-7.71 (2H, m, Ar-H); \(\delta_C\) (100.7 MHz, CDCl\(_3\)) 20.6, 20.7 (2 x q, 3 x C(O)CH\(_3\)), 23.3 (q,
HNC(OC)CH₃, 54.3 (d, C-2), 62.1 (t, C-6), 68.1 (d, C-4), 73.3 (d, C-3), 76.0 (d, C-5), 86.9 (d, C-1), 127.9, 129.0, 131.3 (3 x d, 5 x Ar-C), 132.4 (s, Ar-C), 169.3, 170.0, 170.7, 171.0 (4 x s, 3 x C(O)CH₃, HNC(O)CH₃); m/z (ES⁺) 578 (MMeCNNH₄⁺, 100%).

**N-Acetyl-L-cysteine** (3,4,6-tetra-O-acetyl-2-acetamido-2-deoxy-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 13

![N-Acetyl-L-cysteine](image)

Phenyl 3,4,6-tri-O-acetyl-2-acetamido-2-deoxy-1-selenenylsulfide-β-D-glucopyranoside 52 (165 mg, 0.318 mmol) was dissolved in anhydrous DCM (5 mL) and stirred at room temperature under an atmosphere of argon. Triethylamine (50 µL, 0.318 mmol) was added to the above solution. A solution of N-acetyl-L-cysteine methyl ester 27 (56 mg, 0.318 mmol) in a mixture of anhydrous DCM (5 mL) and anhydrous methanol (4 mL) was slowly added via a syringe pump over a 2 h period. After a 2 h period, t.l.c. (ethyl acetate) indicated the formation of a major product (Rₛ 0.2). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (ethyl acetate) to afford N-acetyl-L-cysteine (3,4,6-tetra-O-acetyl-2-acetamido-2-deoxy-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 13 (126 mg, 74%) as a white amorphous solid; [α]₀²¹ -28.9 (c, 1 in CHCl₃); νₑₘₐₓ (KBr disc) 3309 (br, NH) 1746 (s, C=O) 1659 (s, C=O) cm⁻¹; δₜₜ (400 MHz, CDCl₃) 1.95, 2.03, 2.04, 2.06, 2.09 (15H, 5 x s, 3 x C(O)CH₃, 2 x HNC(O)CH₃), 3.12 (1H, dd, JCH₃H₁ 14.2 Hz, JCH₂₃H₂ 6.7 Hz, CH₃H), 3.34 (1H, dd, JCH₃H₂ 14.2 Hz, JCH₃H₃ 4.8 Hz, CH₂H), 3.79 (3H, s, OCH₃), 3.82 (1H, ddd, J₅₆ 9.9 Hz, J₅₆ 2.4 Hz, J₅₆ 4.6 Hz, H-5), 4.18 (1H, at, J 9.8 Hz, H-2), 4.20 (1H, dd, J₅₆ 2.4 Hz, J₆₆ 12.5 Hz, H-6), 4.26 (1H, dd, J₅₆ 4.6 Hz, J₆₆ 12.5 Hz, H-6), 4.77 (1H, d, J₅₆ 10.4 Hz, H-1), 4.94-4.99 (1H, m, δH), 5.11 (1H, at, J 9.7 Hz, H-4), 5.24 (1H, at, J 9.8 Hz, H-3), 5.89 (1H, d, J₉₂₄ 9.2 Hz, HNC(O)CH₃, H-2), 6.46 (1H, d, J₉₂₄ 7.9 Hz, HNC(O)CH₃, δH); δC (100.7 MHz, CDCl₃) 20.6, 20.7, 20.8 (3 x q, 3 x C(O)CH₃), 23.1, 23.2 (2 x q, 2 x HNC(O)CH₃), 42.0 (t, CH₂H), 52.1 (d, C), 52.7 (d, C-2), 52.8 (q, OCH₃), 62.0 (t, C-6), 68.0 (d, C-4), 73.4 (d, C-3), 76.1 (d, C-5), 90.3 (d, C-1), 169.3, 169.9, 170.2, 170.6, 170.6 (5 x s, 3 x C(O)CH₃, 2 x HNC(O)CH₃, CO₂CH₃); m/z (ES⁺) 597 (MMeCNNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C₂₀H₁₅N₄O₁₁S₂ (MH⁺) 539.1364. Found: 539.1372.
Synthesis of \( N\)-Acetyl-L-cysteine (1-dithio-\( \beta \)-d-glucopyranosyl disulfide) methyl ester 15

1. Lawesson’s reagent, dioxane, reflux, 48 h

Lawesson’s reagent (672 mg, 1.665 mmol) was added to a partial solution of D-glucose 39 (200 mg, 1.110 mmol) in anhydrous dioxane (6 mL) and the reaction mixture heated to 110 °C under an atmosphere of argon for 48 h. After this time, the reaction mixture was cooled to room temperature, filtered through Celite® and concentrated in vacuo. The resulting crude product was then dissolved in pyridine (3 mL) and acetic anhydride (3 mL) added to the solution. The reaction was stirred for 16 h, after which time a few drops of water were added and the reaction left to stir for 10 min. The reaction mixture was extracted with ether (3 x 90 mL), washed with hydrochloric acid (50 mL of a 1M solution), sodium hydrogen carbonate (50 mL of a saturated aqueous solution), and water (2 x 50 mL), dried (MgSO\(_4\)), filtered and concentrated in vacuo. The residue was purified by flash column chromatography (petrol:ethyl acetate, 3:1) to afford 1-S-acetyl-2,3,4,6-tetra-O-acetyl-1-thio-\( \beta \)-d-glucopyranoside 53 (0.2 g, 44%) as a white solid; m.p. 100-102 °C [Lit. 119-120 °C]\(^{20}\); \([\alpha]_D^{20}\) +11.4 (c, 1.10 in CHCl\(_3\)) [Lit. \([\alpha]_D^{23}\) +10.5 (c, 0.6 in CHCl\(_3\))]\(^{20}\); \(\delta_H\) (400 MHz, CDCl\(_3\)) 2.00, 2.02, 2.03, 2.08 (12H, 4 x s, 4 x C(O)CH\(_3\)), 2.39 (3H, s, S(O)CH\(_3\)), 3.82-3.86 (1H, m, H-5), 4.10 (1H, dd, \(J_{5,6} 2.2\) Hz, \(J_{6,6}' 12.5\) Hz, H-6), 4.26 (1H, dd, \(J_{5,6} 4.5\) Hz, H-6'), 5.09-5.15 (2H, m, H-3, H-4), 5.26 (1H, d, \(J_{1,2} 10.6\) Hz, H-1), 5.28 (1H, at, \(J_{2,3} 9.3\) Hz, H-2); \(m/z\) (ES\(^+\)) 465 (MMeCNNH\(_4^+\), 100%).
1-Thio-β-D-glucopyranose$^{21}$ 54

1-S-acetyl-2,3,4,6-tetra-O-acetyl-1-thio-β-D-glucopyranoside 53 (0.2 g, 0.50 mmol) was dissolved in anhydrous methanol (5 mL) and sodium methoxide (27 mg, 0.50 mmol) was added. The mixture was stirred under an atmosphere of argon for 1 h, when t.l.c. (petrol:ethyl acetate, 1:1) indicated formation of a single product (R$_f$ 0.1) and complete consumption of starting material (R$_f$ 0.4). Ion exchange resin (DOWEX 50WX8-200) was added portionwise until the solution was neutralised, at which point the reaction mixture was concentrated in vacuo to yield 1-thio-β-D-glucopyranose 54 (quantitative yield) which was used directly without further purification; [α]$_D^{22}$ +6.0 (c, 1.0 in MeOH); δ$_H$ (400 MHz, CD$_3$OD) 2.61 (1H, d, $J_{1,SH}$ 8.0 Hz, SH), 3.12 (1H, at, $J_{1,2}$ 9.3 Hz, $J_{2,3}$ 9.3 Hz, H-2), 3.30-3.36 (2H, m, H-3, H-5), 3.51 (1H, at, $J_{3,4}$ 9.4 Hz, $J_{4,5}$ 9.4 Hz, H-4), 3.64 (1H, dd, $J_{5,6}$ 1.9 Hz, $J_{6,6'}$ 12.0 Hz, H-6), 3.85 (1H, dd, $J_{5,6}$ 5.3 Hz, $J_{6,6'}$ 12.0 Hz, H-6'), 4.42 (1H, d, $J_{1,2}$ 9.3 Hz, H-1); δ$_C$ (100.7 MHz, CD$_3$OD) 61.8 (t, C-6), 72.1 (d, C-4), 76.4 (d, C-5), 77.2 (d, C-2), 78.2 (d, C-3), 80.9 (d, C-1); m/z (ES') 195 (M-H$^+$, 100%).

Phenyl 1-selenenylsulfide-β-D-glucopyranoside$^3$ 55

1-Thio-β-D-glucopyranose 54 (200 mg, 1.02 mmol) and phenylselenyl bromide (265 mg, 1.12 mmol) were dissolved in anhydrous dioxane (5 mL). The resulting mixture was stirred under an atmosphere of argon at room temperature. After 1 min, t.l.c. (ethyl acetate:methanol, 9:1) indicated the formation of a major product (R$_f$ 0.4). The reaction was quenched with the addition of triethylamine (2 mL). The solution was concentrated in vacuo. The residue was purified by flash column chromatography (ethyl acetate) to afford phenyl 1-selenenylsulfide-β-D-glucopyranoside 55 (94 mg, 26%) as an off white amorphous solid; [α]$_D^{18}$ -93.8 (c, 1 in MeOH) [Lit. [α]$_D^{22}$ -153.0 (c, 1 in MeOH)$^3$]; δ$_H$ (400 MHz, CD$_3$OD) 3.53-3.55 (2H, m, H-3, H-5), 3.61-3.66 (2H, m, H-2, H-4), 3.84 (1H, dd, $J_{5,6}$ 5.1 Hz, $J_{6,6'}$ 11.7 Hz, H-6), 4.04 (1H, dd, $J_{5,6}$ 1.7 Hz, $J_{6,6'}$ 11.3 Hz, H-6'), 4.69 (1H, d, $J_{1,2}$ 9.3 Hz, H-1), 7.47-7.56 (3H, m, Ar-H), 7.98-8.00 (2H, m, Ar-H); δ$_C$ (100.7 MHz, CD$_3$OD) 62.2 (t, C-6), 70.6, 81.5 (2 x d, C-3, C-5), 73.8, 78.7 (2 x d, C-2, C-4), 89.8 (d, C-1), 127.8, 129.3, 130.9 (3 x d, 5 x Ar-C), 133.1 (s, Ar-C).
**N-Acetyl-L-cysteine (1-dithio-β-D-glucopyranosyl disulfide) methyl ester 15**

![Chemical structure](image)

Phenyl 1-selenenylsulfide-β-D-glucopyranoside 55 (90 mg, 0.256 mmol) was dissolved in anhydrous methanol (8 mL) and stirred at room temperature under an atmosphere of argon. A solution of N-acetyl-L-cysteine methyl ester 27 (45 mg, 0.256 mmol) and triethylamine (40 µL, 0.256 mmol) in anhydrous methanol (5 mL) was slowly added via a syringe pump over a 2 h period. After a 2 h period, t.l.c. (ethyl acetate:methanol, 9:1) indicated the formation of a product (R_f 0.2) along with complete consumption of the starting material (R_f 0.4). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (ethyl acetate:methanol, 9:1) to afford N-acetyl-L-cysteine (1-dithio-β-D-glucopyranosyl disulfide) methyl ester 15 (75 mg, 79%) as a white amorphous solid; [α]_D^21 = -12.5 (c, 1 in MeOH); ν_{max} (KBr disc) 3363 (br, NH OH) 1764 (s, C=O) 1653 (s, C=O) cm⁻¹; δ_H (400 MHz, CD_3OD) 2.00 (3H, s, HNC(O)CH₃), 3.02 (1H, dd, J_H_H' 13.8 Hz, J_CH,αH 8.7 Hz, CH,H'), 3.31-3.34 (1H, m, H-5), 3.35-3.37 (2H, m, CH,H', H-4), 3.42 (1H, dd, J 8.0 Hz, J 10.3 Hz, H-3), 3.52 (1H, at, J 9.0 Hz, H-2), 3.71 (1H, dd, J_{5,6} 5.3 Hz, J_{6,6'} 11.9 Hz, H-6), 3.75 (3H, s, OCH₃), 3.89 (1H, dd, J_{5,6} 1.9 Hz, J_{6,6'} 11.9 Hz, H-6'), 4.36 (1H, d, J_{1,2} 9.3 Hz, H-1), 4.90-4.93 (1H, m, αH); δ_C (100.7 MHz, CD_3OD) 21.4 (q, HNC(O)CH₃), 40.6 (t, CH,H'), 51.9 (d, αC), 52.4 (q, OCH₃), 61.9 (t, C-6), 70.2 (d, C-4), 71.4 (d, C-2), 78.4 (d, C-3), 81.5 (d, C-5), 90.5 (d, C-4), 171.8, 172.4 (2 x s, HNO(O)CH₃, CO₂CH₃); m/z (ES⁺) 394 (MNa⁺, 90%), 430 (MMeCNNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C_{12}H_{21}NNaO₈S₂ (MNa⁺) 394.0601. Found: 394.0601.
Synthesis of N-Acetyl-L-cysteine (2-acetamido-2-deoxy-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 17

Scheme S15.

1-Thio-2-acetamido-2-deoxy-β-D-glucopyranose\(^3\) 56

1-thio-3,4,6-Tri-O-acetyl-2-acetamido-2-deoxy-β-D-glucopyranose 51 (0.66 g, 1.829 mmol) was dissolved in anhydrous methanol (10 mL) and sodium methoxide (0.32 g, 5.961 mmol) was added. After 30 min, t.l.c. (ethyl acetate) indicated the formation of a single product (\(R_f\) 0) and the absence of starting material (\(R_f\) 0.2). Ion exchange resin (DOWEX 50WX8-200) was added portionwise until the solution was neutralised, at which point the reaction mixture was concentrated in vacuo. Recrystallisation from methanol/ethyl acetate yielded 1-thio-2-acetamido-2-deoxy-β-D-glucopyranose 56 (0.38 g, 87%) as a white crystalline solid; m.p. 174-176 °C (methanol/ethyl acetate) [Lit. 177-179 °C (methanol/ethyl acetate)]\(^3\); [\(\alpha\)]\(D\)\(^{21}\) -12.1 (c, 1 in MeOH) [Lit. [\(\alpha\)]\(D\)\(^{22}\) -10.4 (c, 1 in MeOH)]\(^3\); \(\delta_h\) (400 MHz, CD\(_3\)OD) 2.00 (3H, s, HNC(O)CH\(_3\)), 3.27-3.37 (2H, m, H-4, H-5), 3.41 (1H, at, \(J\) 9.0 Hz, H-3), 3.65 (1H, dd, \(J_{5,6} \) 5.6 Hz, \(J_{6,6'}\) 11.9 Hz, H-6), 3.87 (1H, dd, \(J_{5,6} \) 2.0 Hz, \(J_{6,6'}\) 12.0 Hz, H-6'), 4.56 (1H, d, \(J_{1,2} \) 10.0 Hz, H-1), 8.15 (1H, d, \(J_{NH,H-2} \) 8.8 Hz, HNC(O)CH\(_3\)); \(\delta_c\) (100.7 MHz, CD\(_3\)OD) 21.9 (q, HNC(O)CH\(_3\)), 58.9 (d, C-2), 61.8 (t, C-6), 70.8 (d, C-4), 76.0 (d, C-3), 79.9 (d, C-1), 81.5 (d, C-5), 172.8 (s, HNC(O)CH\(_3\)); \(m/z\) (ES\(^+\)) 236 (M-H\(^+\), 100%).
Phenyl 2-acetamido-2 deoxy-1-selenenylsulfide-β-D-glucopyranoside 57

1-Thio-2-acetamido-2-deoxy-β-D-glucopyranose 56 (248 mg, 1.05 mmol) and phenylselenyl bromide (271 mg, 1.15 mmol) were dissolved in a mixture of anhydrous dioxane (5 mL) and anhydrous methanol (3 mL). The resulting mixture was stirred under an atmosphere of argon at room temperature. After 1 min, t.l.c. (ethyl acetate:methanol, 9:1) indicated the formation of a major product (Rf 0.4). The reaction was quenched with the addition of triethylamine (3 mL). The solution was concentrated in vacuo. The residue was purified by flash column chromatography (ethyl acetate:methanol, 9:1) to afford phenyl 2-acetamido-2 deoxy-1-selenenylsulfide-β-D-glucopyranoside 57 (271 mg, 66 %) as an white amorphous solid; [α]D 21 -171.3 (c, 1 in MeOH) [Lit. [α]D 22 -174.0 (c, 1 in MeOH)]; δH (400 MHz, CD3OD) 1.96 (3H, s, HNC(O)CH3), 3.31-3.34 (1H, m, H-5), 3.36 (1H, dd, J5,6 5.3 Hz, J6,6' 11.9 Hz, H-6), 3.84 (1H, dd, J5,6' 2.0 Hz, J6,6' 11.9 Hz, H-6'), 3.87 (1H, at, J 10.0 Hz, H-2), 4.64 (1H, d, J1,2 10.3 Hz, H-1), 7.27-7.34 (3H, m, Ar-H), 7.71-7.74 (2H, m, Ar-H); δC (100.7 MHz, CD3OD) 21.9 (q, HNC(O)CH3), 56.1 (d, C-2), 61.9 (t, C-6), 70.8 (d, C-5), 76.0 (d, C-3), 81.4 (d, C-4), 89.5 (d, C-1), 127.6, 129.1 (2 x d, 5 x Ar-C), 130.8 (s, Ar-C), 172.6 (s, HNC(O)CH3).

N-Acetyl-L-cysteine (2-acetamido-2-deoxy-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 17

Phenyl 3,4,6-tri-O-acetyl-2-acetamido-2-deoxy-1-selenenylsulfide-β-D-glucopyranoside 57 (112 mg, 0.286 mmol) and triethylamine (20 µL, 0.143 mmol) were dissolved in anhydrous methanol (8 mL) and stirred at room temperature under an atmosphere of argon. A solution of N-acetyl-L-cysteine methyl ester 27 (17 mg, 0.095 mmol) in anhydrous methanol (5 mL) was added dropwise over a 10 min period. After 6 h, t.l.c. (ethyl acetate:methanol, 9:1) indicated the formation of a product (Rf 0.1) along with complete consumption of the starting material (Rf 0.2). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column
chromatography (ethyl acetate:methanol, 9:1) to afford N-acetyl-L-cysteine (2-acetamido-2-deoxy-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 17 (37 mg, 94%) as a white amorphous solid; [α]$_D$²⁵° -74.1 (c, 1 in MeOH); $\nu_{max}$ (KBr disc) 3363 (br, NH OH) 1737 (s, C=O) 1654 (s, C=O) cm$^{-1}$; $\delta$H (500 MHz, CD$_3$OD) 1.99, 2.00 (6H, 2 x s, 2 x HNC(O)CH$_3$), 3.07 (1H, dd, $J_{CH,H} 13.9$ Hz, $J_{CH,H'} 8.7$ Hz, CH$_2$H$'$), 3.30-3.39 (3H, m, H$_3$, H-4, CH$_2$H$'$), 3.50-3.54 (1H, m, H$_2$, H-5), 3.72-3.78 (2H, m, H-6, H-6$'$), 3.79 (3H, s, OCH$_3$), 3.92 (1H, at, $J_{1,2} 10.3$ Hz, H-2), 4.57 (1H, d, $J_{1,2} 10.3$ Hz, H-1), 4.73-4.77 (1H, m, $\alpha$H), 7.32 (1H, d, $J_{H,H+2} 7.5$ Hz, HNC(O)CH$_3$, H-2), 7.74 (1H, d, $J_{H,H+2} 7.0$ Hz, HNC(O)CH$_3$, H$'$); $\delta$C (125.8 MHz, CD$_3$OD) 22.4, 22.9 (2 x q, 2 x HNC(O)CH$_3$), 41.9 (t, CH$_2$H$'$), 52.9 (q, OCH$_3$), 53.6 (d, $\alpha$C), 55.6 (d, C-2), 62.9 (t, C-6), 71.7 (d, C-4), 77.1 (d, C-5), 82.6 (d, C-3), 91.3 (d, C-1), 172.8, 173.4, 173.5 (3 x s, 2 x HNC(O)CH$_3$, CO$_2$CH$_3$); $m/z$ (ES$^+$) 471 (MMeCNNH$_4^+$, 100%); HRMS (ES$^+$) Calcd. for C$_{14}$H$_{24}$N$_2$NaO$_6$S$_2$ (MNa$^+$) 435.0869. Found: 435.0866.

**General procedures for peptide synthesis**

General procedure 1 (GP 1): to a ~0.1M solution of the amine and appropriate amino acid (1.1 equivalents) in anhydrous DMF were added HBTU (1.1 equivalents), HOBT (0.37 equivalents) and DIPEA (2 equivalents). After t.l.c. analysis showed complete consumption of starting material and formation of a major product, the reaction mixture was concentrated in vacuo. The residue was diluted with DCM, washed with sodium hydrogen carbonate (saturated aqueous solution), potassium hydrogen sulfate (1N aqueous solution), and brine, dried (MgSO$_4$), filtered and concentrated in vacuo.

General procedure 2 (GP 2): a ~0.1M solution of the Fmoc building block in DCM (~c = 0.1M) was treated with 1.05 equiv. DBU. After t.l.c. analysis showed complete consumption of starting material and formation of a major product, the reaction mixture was concentrated in vacuo ~20% of the original volume. The amine was subsequently purified by flash column chromatography. In case of the “one-pot” procedure (i.e. deprotection-coupling), the reaction mixture was not concentrated after completion but treated with 1.0 equivalents of HOBT and this solution was used for the amino acid coupling as described in GP 1.

General procedure 3 (GP 3): a solution of the amine in pyridine (~c = 0.1M) was cooled to 0°C and treated with acetic anhydride (5 mL mmol$^{-1}$). To speed up the reaction 0.33 equivalents of DMAP were added. After t.l.c. analysis showed complete consumption of starting material and formation of a major product, the reaction mixture was concentrated in vacuo. The residue was diluted with DCM, washed with sodium
hydrogen carbonate (saturated aqueous solution), potassium hydrogen sulfate (1N aqueous solution), and brine, dried (MgSO₄), filtered and concentrated in vacuo.

**Synthesis of Ac-Cys-Ser(tBu)-Gly-OEt 58**

\[
\begin{align*}
\text{Fmoc-Ser(tBu)-OH} + \text{HCl H-Gly-OEt} & \rightarrow \text{Fmoc-Ser(tBu)-Gly-OEt} \\
\text{Fmoc-Ser(tBu)-OH} + \text{HCl H-Gly-OEt} & \rightarrow \text{Fmoc-Ser(tBu)-Gly-OEt} \\
\text{Fmoc-Ser(tBu)-OH} + \text{HCl H-Gly-OEt} & \rightarrow \text{Fmoc-Ser(tBu)-Gly-OEt} \\
\end{align*}
\]

**Scheme S16.** Reagents and Conditions: (i) HBTU, HOBt, DiPEA, DCM, DMF (yield 59: 99%); (ii) (a) DBU, DCM; (b) HOBt; (c) Fmoc-Cys(Tr)-OH, HBTU, HOBt, DiPEA, DCM, DMF (yield 60: 89%); (iii) DBU, DCM (yield 61: 86%). (iv) Ac₂O, pyridine (yield 62: 84%). (v) TFA/DCM (5/95 v/v), iPr₂SiH (yield 58: 73%).

**N-fluorenyl methoxycarbonyl-O-tert-butyl-L-serine-glycine ethyl ester 59**

Fmoc-Ser(tBu)-OH (5.00 g, 13.0 mmol) and HCl·Gly-OEt (2.00 g, 14.3 mmol) were treated according to GP 1; purification by flash column chromatography (diethyl ether) gave Fmoc-Ser(tBu)-Gly-OEt 59 as a white solid; m.p. 119 ºC; Yield: 99%; R₆ 0.6 (diethyl ether); [α]D° +23.2 (c, 1 in CHCl₃); νmax (KBr disc) 3300 (br, NH) 1726 (s, C=O) 1656 (s, C=O) cm⁻¹; δH (400 MHz, CDCl₃) 1.15 (9H, s, C(CH₃)₃), 1.21 (3H, dd, J 7.1 Hz, partially obscured by following resonance, OCH₂CH₃), 3.34 (1H, at, J 8.4 Hz, CH,H’ser), 3.77 (1H, dd, J 3.8 Hz, J 8.4 Hz, CH,H’ser), 3.99 (2H, ABX system, J 13.3 Hz, J 18.3 Hz, αHgly), 4.10 (4H, m, αHser, H₁Fmoc, OCH₂CH₃), 4.32 (2H, d, J 6.8 Hz, CH₂Fmoc), 5.72 (1H, d, J 5.2 Hz, NH), 7.18-7.36 (5H, m, 4xH₁Fmoc, NHamide), 7.55 (2H, d, J 7.4 Hz, H₁Fmoc), 7.70 (1H, d, J 7.5 Hz, NH_Fmoc); δC (100.7 MHz, CDCl₃) 13.5 (q, OCH₂CH₃), 26.7 (q, C(CH₃)₃), 40.9 (t, αCgly), 46.5 (d, CH₁Fmoc), 54.1 (d, αCser), 60.7 (t, CH,H’ser), 61.4 (t, OCH₂CH₃), 66.5 (s, C(CH₃)₃), 73.4 (t, CH₂Fmoc), 119.4, 124.6, 126.5, 127.1 (4 x d, 4 x C₁Fmoc), 140.6, 143.2, 143.3 (3 x s, 3 x C₁Fmoc), 155.2 (s, CCO_Fmoc), 169.2,
171.2 (2 x s, 2 x CO); m/z (ES⁺) 527 (MMeCNNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C₅₂H₃₂N₂O₆ (MNa⁺) 491.2153. Found: 491.2136.

**N-fluorenyl methoxycarbonyl-S-trityl-L-cysteine-O-tert-butyl-L-serine-glycine ethyl ester 60**

Fmoc-Ser(tBu)-Gly-OEt 59 (2.50 g, 5.34 mmol) was deprotected according to GP 2 and coupled with Fmoc-Cys(Tr)-OH according to GP 1; purification by flash column chromatography (diethyl ether) gave 60 as a colourless foam; Yield: 89%; Rₜ 0.6 (diethyl ether); [α]D₁₈ +2.0 (c, 0.5 in CHCl₃) 1750 (s, C=O) 1650 (s, C=O) cm⁻¹; δₜH (100.7 MHz, CDCl₃) 13.8 (q, OCH₂C₃H₃), 27.0 (q, C(CH₃)₃), 33.5 (t, CH₂H’cys), 40.8 (t, αCgly), 46.7 (d, CHFmoc), 52.9, 53.7 (2 x d, αCser, αCcys), 60.8 (2 x t, OCH₂CH₃, CH₂H’ser), 66.9 (t, CH₂Fmoc), 73.6 (s, C(CH₃)₃), 119.6, 124.7 (2 x d, 3 x CTr), 126.6-127.8 (C₂Fmoc), 140.9, 143.3, 143.5, 143.9 (4 x s, 3 x C₂Fmoc, CTr), 155.5 (s, COFmoc), 168.9, 169.6, 169.8 (3 x s, 2 x COamide, COester); m/z (ES⁺) 872 (MMeCNNH₄⁺, 100%); HRMS (ES⁺) Calcd. for C₄₈H₅₁N₃O₇S (MNa⁺) 836.3340. Found: 836.3316.

**S-trityl-L-cysteine-O-tert-butyl-L-serine-glycine ethyl ester 61**

Fmoc-Cys(Tr)-Ser(tBu)-Gly-OEt 61 (1.00 g, 1.23 mmol) was deprotected according to GP 2; purification by flash column chromatography (DCM→DCM:methanol, 9:1) gave H-
Cys(Tr)-Ser(fBu)-Gly-OEt 61 as a yellow oil; Yield: 86%; Rf 0.5 (DCM:methanol, 9:1); δH (400 MHz, CDCl3) 1.17 (9H, s, C(CH3)3), 1.25 (3H, at, J 7.2 Hz, OCH2CH3), 2.55 (1H, at, J 8.1 Hz, CH,H’cys), 2.75 (1H, dd, J 4.6 Hz, J 12.8 Hz, CH,H’cys), 2.83 (1H, dd, J 4.2 Hz, J 8.1 Hz, H;cys), 3.33 (1H, at, J 7.7 Hz, CH,H’ser), 3.80 (1H, dd, J 4.0 Hz, J 8.8 Hz, CH,H’ser), 3.95 (2H, d, J 5.2 Hz, Hgly), 4.18 (2H, at, J 7.2 Hz, OCH2CH3), 4.40 (1H, dd, J 4.0 Hz, J 7.3 Hz, H, NH;amide), 7.20 (1H, d, J 7.2 Hz, NH;amide); δC (100.7 MHz, CDCl3) 13.7 (q, OCH2CH3), 27.0 (q, C(CH3)3), 36.9 (t, CH,H’cys), 40.9 (t, αCgly), 52.4, 53.7 (2 x d, αCser, αCcys), 60.8, 66.4 (2 x t, OCH2CH3, CH,H’ser), 73.5 (s, C(CH3)3), 126.7, 127.6, 129.1 (3 x d, 3 x CTr), 144.1 (s, CTr), 169.0, 170.0, 173.0 (3 x s, 2 x COamide, COester); m/z (ES+) 650 (MMeCNHH4+, 100%); HRMS (ES+) Calcd. for C33H42N3NaO6S (MNa+) 614.2659. Found: 614.2647.

N-acetyl-S-trityl-L-cysteine-O-tert-butyl-L-serine-glycine ethyl ester 62

H-Cys(Tr)-Ser(fBu)-Gly-OEt 61 (351 mg, 593 μmol) was treated according to GP 3; purification by flash column chromatography (6% methanol in DCM) furnished Ac-Cys(Tr)-Ser(fBu)-Gly-OEt 62 as a white solid; m.p. 191 °C; Yield: 84%; Rf 0.5 (6% methanol in DCM); [α]D18° +14.4 (c, 0.25 in CHCl3); υmax (KBr disc) 3260 (br, NH) 1757 (s, C=O) 1640 (s, C=O) cm⁻¹; alternatively, Fmoc-Cys(Tr)-Ser(fBu)-Gly-OEt 60 (1.00 g, 1.15 mmol) was deprotected according to GP 2 and acetylated following GP 3b; Yield: 81% over 2 steps; δH (400 MHz, CDCl3) 1.18 (9H, s, C(CH3)3), 1.25 (3H, at, J 7.2 Hz, OCH2CH3), 1.90 (3H, s, C(O)CH3), 2.65 (1H, at, J 6.6 Hz, CH,H’cys), 2.75 (1H, dd, J 5.9 Hz, J 6.6 Hz, CH,H’cys), 3.35 (1H, dd, J 6.0 Hz, J 8.8 Hz, CH,H’ser), 3.75 (1H, dd, J 5.4 Hz, J 8.0 Hz, αHgly), 3.88 (3H, m, αHgly, CH,H’ser, αHcys), 4.18 (2H, dd, J 7.0 Hz, J 14.0 Hz, OCH2CH3), 4.40 (1H, dd, J 3.3 Hz, J 7.3 Hz, αHser), 6.05 (1H, d, J 7.1 Hz, NH;amide), 6.70 (1H, d, J 7.4 Hz, NH;amide), 7.20-7.45 (16H, m, 15 x HTr, NH;amide); δH (100.7 MHz, CDCl3) 13.9 (q, OCH2CH3), 22.7 (q, C(O)CH3), 27.1 (q, C(CH3)3), 33.3 (t, CH,H’cys), 40.9 (t, αCgly), 52.1, 53.1 (2 x d, αCser, αCcys), 60.7, 60.9 (2 x t, OCH2CH3, CH,H’ser), 73.7 (s, C(CH3)3), 126.7, 127.9, 129.2 (3 x d, 3 x CTr), 144.0 (s, CTr), 169.0, 169.8, 169.9 (4 x CO); m/z (ES+) 692 (MMeCNHH4+, 100%); HRMS (ES+) Calcd. for C35H43N3NaO6S (MNa+) 656.2765. Found: 656.2766.
Synthesis of Ac-Cys-Gly-Thr(tBu)-Gly-OEt 63

\[
\text{Fmoc-Thr(tBu)-OH} + \text{HCl H-Gly-OEt} \rightarrow \text{Fmoc-Thr(tBu)-Gly-OEt}
\]

**Scheme S17.** Reagents and Conditions: (i) HBTU, HOBt, DiPEA, DCM, DMF (yield 64: 89%); (ii) (a) DBU, DCM; (b) HOBt; (c) Fmoc-Gly-OH, HBTU, HOBt, DiPEA, DCM, DMF (yield 65: 85%); (iii) DBU, DCM (yield 66: 82%); (iv) Fmoc-Cys(Tr)-OH, HBTU, HOBt, DiPEA, DCM, DMF (yield: 85%); (v) DBU, DCM (yield 67: 70% from 65); (vi) \(\text{Ac}_2\text{O},\) pyridine (yield 69: 82%); (vii) TFA/DCM (5/95 v/v), \(\text{iPr}_3\text{SiH}\) (yield 63: 38%).

**N-fluorenly methoxycarbonyl-L-threonine-glycine ethyl ester 64**

Fmoc-Thr(tBu)-OH (5.00 g, 12.6 mmol) and HCl•H-Gly-OEt (2.11 g, 15.1 mmol) were treated according to GP 1; purification by flash column chromatography (petrol:diethyl ether, 1:3) gave 64 as a white solid; m.p. 93 °C; Yield: 89%; R, 0.8 (diethyl ether); \([\alpha]_D^{18}\) +19.2 (c, 1 in CHCl₃); \(\nu_{\text{max}}\) (KBr disc) 3310 (br, NH) 1742 (s, C=O) 1670 (s, C=O) cm⁻¹; \(\delta_H\) (400 MHz, CDCl₃) 1.10 (3H, d, J 6.4 Hz, CH₃thr), 1.30 (12H, m, OCH₂CH₃, C(CH₃)₃), 4.07 (2H, ABX system, \(\alpha\)Hgly), 4.18-4.26 (5H, m, \(\alpha\)Hthr, CHthr, H₁Fmoc, OCH₂CH₃), 4.40 (2H, d, J 7.5 Hz, CH₂Fmoc), 6.03 (1H, d, J 5.0 Hz, NH), 7.31 (2H, at, J 7.4 Hz, H₁Fmoc), 7.40 (2H, at, J 7.5 Hz, H₂Fmoc), 7.61 (2H, d, J 7.6 Hz, H₃Fmoc), 7.64 (1H, m, NH), 7.75 (2H, d, J 7.5 Hz, H₄Fmoc); \(\delta_C\) (100.7 MHz, CDCl₃) 13.9 (q, OCH₂CH₃), 16.6 (q, CH₃thr), 27.9 (q, C(CH₃)₃), 41.3 (t, \(\alpha\)Cgly), 46.9 (d, CH₁Fmoc), 58.3 (d, \(\alpha\)Cthr), 61.1 (t, OCH₂CH₃), 66.4 (d, CHthr), 66.6 (t, CH₂Fmoc), 75.3 (q, C(CH₃)₃), 119.7, 124.9, 126.8, 127.4 (4 x d, 4 x CFmoc), 141.0 (s, 2 x CFmoc), 143.4, 143.7, (2 x s, 2 x CFmoc), 155.7 (s, COFmoc), 169.1,
169.3 (2 x d, 2 x CO); m/z (ES+): 505 (MNa+, 100%); HRMS (ES+) Calcd. for C_{27}H_{34}N_{2}O_{6} (MNa+) 505.2309. Found: 505.2304.

**N-fluorenly methoxycarbonyl-glycine-O-tert-butyl-L-threonine-glycine ethyl ester 65**

Fmoc-Thr(tBu)-Gly-OEt 64 (2.60 g, 5.39 mmol) was deprotected according to GP 1 and the free amine was coupled with Fmoc-Gly-OH following GP 2; purification by flash column chromatography (petrol:diethyl ether, 1:1→DCM→5% methanol in DCM) furnished Fmoc-Gly-Thr(tBu)-Gly-OEt 65 as a foam; Yield: 85%; Rf 0.4 ([8% methanol in DCM]); [α]_D^{18} +23.6 (c, 0.5 in CHCl_3) 1726 (s, C=O) 1656 (s, C=O) cm^{-1}; δ_H (400 MHz, CDCl_3) 1.05 (3H, d, J_{6.3} Hz, CH_3thr), 1.25 (3H, t, J_{7.2} Hz, OCH_2CH_3), 1.28 (9H, s, C(CH_3)_3), 4.05-4.11 (4H, ABX system, α_Hgly), 4.16-4.22 (4H, m, CH^{Fmoc}, CHthr, OCH_2CH_3), 4.38 (2H, d, J_{7.0} Hz, CH_2^{Fmoc}), 4.44 (1H, at, J_{4.6} Hz, α_Hser), 5.80 (1H, m, NH), 7.23 (1H, d, J_{5.6} Hz, NH^{amide}), 7.30 (2H, m, H^{Fmoc}), 7.37 (2H, at, J_{7.4} Hz, H^{Fmoc}), 7.58 (2H, d, J_{7.4} Hz, H^{Fmoc}), 7.68 (1H, at, J_{5.0} Hz, NH^{amide}), 7.74 (2H, d, J_{7.5} Hz, NH^{Fmoc}); δ_C (100.7 MHz, CDCl_3) 14.0 (q, OCH_2CH_3), 17.1 (q, CH_3thr), 28.0 (q, C(CH_3)_3), 41.4, 44.2 (2 x t, 2 x α_Cgly), 46.9 (d, CH^{Fmoc}), 57.4 (d, α_Cthr), 61.4 (t, OCH_2CH_3), 66.0, 67.1 (2 x t, CH_2^{Fmoc}, CHthr), 75.5 (s, C(CH_3)_3), 119.8, 125.0, 126.9, 127.6 (4 X d, C^{Fmoc}), 141.1 (s, 2 x C^{Fmoc}), 143.7 (s, 2 x C^{Fmoc}), 156.5 (s, CO^{Fmoc}), 168.8, 169.3, 169.5 (3 x s, 3 x CO); m/z (ES+) 598 (MMeCNH_4^+, 100%); HRMS (ES+) Calcd. for C_{29}H_{37}N_{2}NaO_{7} (MNa+) 562.2524. Found: 562.2525.

**N-fluorenly methoxycarbonyl-S-trityl-L-cysteine-glycine-O-tert-butyl-L-threonine-glycine ethyl ester 67**

Fmoc-Gly-Thr(tBu)-Gly-OEt 65 (108 mg, 200 µmol) was deprotected following GP 2; (H-Gly-Thr(tBu)-Gly-OEt: Rf 0.3 (DCM:methanol, 9:1). After t.l.c. showed completion (30 min), the solution was concentrated in vacuo and the residue purified by flash column chromatography (DCM→DCM:methanol, 9:1). The amine (66, 52 mg,
164 μmol, 82%) was used directly for the coupling with Fmoc-Cys(Tr)-OH following GP 2; after stirring the reaction mixture overnight, t.l.c. analysis showed total consumption of starting material; purification by flash column chromatography (DCM→DCM:methanol, 9:1) gave 67 as a white solid; m.p. 117 ºC; Yield: 85%; Rf 0.4 (5% methanol in DCM); [α]D18 +14.6 (c, 0.5 in CHCl3); vmax (KBr disc) 3300 (br, NH) 1742 (s, C=O) 1632 (s, C=O) cm⁻¹; δH (400 MHz, CDCl3) 0.91 (3H, d, J 6.2 Hz, CH₃ thr), 1.13 (3H, t, J 7.1 Hz, OCH₂CH₃), 1.17 (9H, s, C(CH₃)₃), 2.61 (2H, m, CH₂H‘cys), 3.83 (2H, m, αHgly), 3.88-4.00 (3H, m, 2 x αHgly, αCcys), 4.00-4.13 (4H, m, CH₃Fmoc, OCH₂CH₃, CHthr), 4.30 (3H, m, αHthr, CH₂Fmoc), 5.40 (1H, d, J 6.9 Hz, NH), 7.10 (1H, m, NH), 7.10-7.22 (11H, m, 11 x Ar-H), 7.26-7.33 (8H, m, 8 x Ar-H), 7.51 (2H, m, H₂Fmoc, NH), 7.65 (2H, dd, J 5.2 Hz, J 7.4 Hz, NHFmoc); δC (100.7 MHz, CDCl3) 14.0 (q, OCH₂CH₃), 17.1 (q, CH₂thr), 28.0 (q, C(CH₃)₃), 41.4, 43.0 (2 x t, 2 x αCgły), 33.6 (t, CH₂H‘cys), 47.0 (d, CH₃Fmoc), 53.8 (d, αCcys), 57.3 (d, αCthr), 61.3 (t, OCH₂CH₃), 66.0, 67.1 (2 x t, CH₂Fmoc, CHthr), 75.4 (s, C(CH₃)₃), 119.8, 125.0, 126.7, 126.9, 127.6, 129.5 (6 x, d, C₃Fmoc, 141.1, 143.6, 143.7, 144.3 (4 x s, C₃Fmoc, 155.9 (s, COFmoc), 168.0, 169.3, 170.5 (3 x s, 4 x CO); m/z (ES⁺) 907 (MNa⁺, 100%); HRMS (ES⁺) Calcd. for C₅₁H₅₆N₅O₉S (MNa⁺) 907.3711. Found: 907.3712.

**N-acetyl-S-trityl-L-cysteine-glycine-O-tert-butyl-L-threonine-glycine ethyl ester 69**

![Structure of 69](image)

Fmoc-Cys(Tr)-Gly-Thr(tBu)-Gly-OEt 67 was synthesised from Fmoc-Gly-Thr(tBu)-Gly-OEt on a 4.36 mmol scale, however, in this case the crude tetrapeptide was used crude during the next removal of the Fmoc group on the cysteine residue according to GP 2; purification by flash column chromatography (DCM→DCM:methanol, 9:1) gave H-Cys(Tr)-Gly-Thr(tBu)-Gly-OEt 68, 2.03 g, 3.06 mmol) as a foam; Yield: 70% from Fmoc-Gly-Thr(tBu)-Gly-OEt; Rf 0.5 (8% methanol in DCM); m/z (ES⁺) 721 (MMeCNNH₄⁺, 100%);

Next, H-Cys(Tr)-Gly-Thr(tBu)-Gly-OEt (1.00 g, 1.51 mmol) was treated with acetic anhydride (10 mL) and pyridine (10 mL) for 20 h. The reaction mixture was diluted with ethyl acetate (100 mL), washed with sodium hydrogen carbonate (saturated aqueous solution), hydrochloric acid (1N aqueous solution), and brine, dried (MgSO₄), filtered and concentrated in vacuo. The residue was purified by flash column chromatography (petrol:ethyl acetate, 1/0→0/1→5% methanol in ethyl acetate) yielding 69 as a glassy
oil; Yield: 82%; Rf 0.5 (8% methanol in DCM); [α]_D^18 +15.0 (c, 1 in CHCl₃); νmax (KBr disc) 3312 (br, NH) 1734 (s, C=O) 1656 (s, C=O) cm⁻¹; δH (400 MHz, CD₂OD) 1.01 (3H, d, J 6.4 Hz, CH₃th), 1.13-1.17 (12H, m, OCH₂CH₃, C(CH₃)₃), 1.91 (3H, s, C(O)CH₃), 2.58 (1H, dd, JCH,H 13.0 Hz, JCH,CH₃ 5.9 Hz, CH₃H'cys), 2.71 (1H, dd, JCH,H 13.0 Hz, JCH,CH₃ 5.9 Hz, CH₃H'cys), 3.81-3.92 (1H, d, J 4.9 Hz, αHgly), 3.92-3.98 (1H, d, J 5.2 Hz, αHgly), 4.01-4.09 (2H, m, 2 x αHgly), 4.12 (1H, m, CHthr), 4.19 (3H, m, OCH₂CH₃, αHcys), 4.40 (1H, dd, J 3.8 Hz, J 5.9 Hz, αHthr), 6.25 (1H, m, NH amide), 6.88 (1H, at, J 5.0 Hz, NH amide), 7.19-7.30 (11H, m, 10 x H₂T, NH amide), 7.63 (1H, t, J 5.1 Hz, NH amide), 7.41 (5H, m, 5 x H₃T); δC (100.7 MHz, CD₂OD) 14.1 (q, OCH₂CH₃), 17.8 (q, CH₃thr), 23.0 (q, C(O)CH₃), 28.1 (q, C(CH₃)₃), 33.2 (t, CH,H'cys), 41.5, 43.2 (2 x t, 2 x αGly), 52.0 (d, αCcys), 57.5 (d, αCthn), 61.4 (t, OCH₂CH₃), 66.1 (t, CHthr), 75.5 (s, C(CH₃)₃), 126.8, 128.0, 129.5 (3 x d, 3 x C₄T), 144.4 (s, C₃T), 168.1, 169.4, 169.5, 170.4, 170.6 (5 x s, 5 x CO); m/z (ES⁺) 763 (MNa⁺, 100%); HRMS (ES⁺) Calcd. for C₉₈H₇₈N₆O₇S (MNa⁺) 727.3136. Found: 727.3135.

**N-acetyl-L-cysteine-glycine-O-tert-butyl-L-threonine-glycine ethyl ester 63**

![Chemical Structure](image)

Ac-Cys(Tr)-Gly-Thr(tBu)-Gly-OEt 68 (868 mg, 1.23 mmol) was dissolved in DCM (14 mL) and treated with iPr₃SiH (1.6 mmol, 327 µL) and trifluoroacetic acid (0.75 mL). After 6 h t.l.c. (DCM:methanol, 9:1) showed complete consumption of starting material and the formation of two lower running spots. The reaction mixture was co-evaporated with dry toluene and purified by flash column chromatography (petrol:ethyl acetate, 10/1→1/1→ethyl acetate→10% methanol in ethyl acetate→20% methanol in ethyl acetate) to give 63 as a foam; Yield: 38%; Rf 0.4 (ethyl acetate:methanol, 9:1); δH (400 MHz, CD₂OD) 1.12 (3H, d, J 6.3 Hz, CH₃th), 1.24 (9H, s, C(CH₃)₃), 1.30 (3H, at, J 7.1 Hz, OCH₂CH₃), 2.05 (3H, s, C(O)CH₃), 2.83 (2H, d, J 6.1 Hz, CH,H'cys), 3.88-4.06 (4H, m, αHgly), 4.17 (1H, m, CHthn), 4.23 (2H, dd, J 7.1 Hz, J 14.1 Hz, OCH₂CH₃), 4.45 (1H, at, J 3.3 Hz, αHthn), 4.58 (1H, at, J 6.1 Hz, αHcys), 7.56 (1H, d, J 7.6 Hz, NH), 7.90 (1H, at, J 5.6 Hz, NH), 8.03 (1H, d, J 7.6 Hz, NH), 8.36 (1H, at, J 5.6 Hz, NH); δC (100.7 MHz, CD₂OD) 13.8 (q, OCH₂CH₃), 17.8 (q, CH₃thn), 22.4 (q, C(O)CH₃), 27.9 (q, C(CH₃)₃), 34.3 (t, CH,H'cys), 41.2, 42.9 (2 x t, 2 x αGly), 54.6, 57.6 (2 x d, αCthn, αCcys), 61.4 (t, OCH₂CH₃), 66.3 (t, CHthn), 75.3 (s, C(CH₃)₃), 169.1-
171.3 (CO); m/z (ES$^+$) 521 (MMeCNNH$_4^+$, 100%); HRMS (ES$^+$) Calcd. for C$_{19}$H$_{34}$N$_4$NaO$_7$S (MNa$^+$) 485.2040. Found: 485.2037.

Synthesis of $N$-Acetyl-L-cysteine-(2,3,4,6-tetra-O-acetyl-1-dithio-$\beta$-D-glucopyranosyl disulfide)-$O$-tert-butyl-L-serine-glycine ethyl ester 19

Scheme S18.

$N$-Acetyl-L-cysteine-(2,3,4,6-tetra-O-acetyl-1-dithio-$\beta$-D-glucopyranosyl disulfide)-$O$-tert-butyl-L-serine-glycine ethyl ester 19

Ac-Cys(Tr)-Ser(tBu)-Gly-OEt 58 (250 mg, 394 µmol) was dissolved in DCM (10 mL) and treated with iPr$_3$SiH (513 µmol, 105 µL) and trifluoroacetic acid (0.5 mL). After 1 h the reaction mixture was co-evaporated with dry toluene (2×25 mL) and a solution of this tripeptide and triethylamine (394 µmol, 55 µL) in a mixture of DCM/methanol (9/1 v/v, 10 mL) was subsequently added dropwise (30 min period) to a solution of 2,3,4,6-tetra-O-acetyl-$\beta$-D-glucopyranosyl phenyl thiosulfonate 42 (398 mg, 0.79 mmol) in DCM/methanol (9/1 v/v, 10 mL). After stirring under an atmosphere of argon for 1 h 30 min, t.l.c. (6% methanol in DCM) showed complete consumption of starting material and formation of a major product ($R_f$ 0.4). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (DCM:methanol, 9:1) yielding 19 (137 mg, 46% over 2 steps) as an oil; $[\alpha]_D^{18}$ -159.2 (c, 0.5 in CHCl$_3$); $\nu_{\text{max}}$ (thin film) 3300 (br, NH) 1750 (s, C=O) 1643 (s, C=O) cm$^{-1}$; $\delta_H$ (400 MHz, CDCl$_3$) 1.16 (9H, s, C(CH$_3$)$_3$), 1.23 (3H, at,
A solution of Ac-Cys-Gly-Thr(tBu)-Gly-OEt 63 (214 mg, 463 µmol) in DCM/methanol (6/2 v/v, 8 mL) and triethylamine (463 µmol, 65 µL) was added dropwise (3 mL h⁻¹) to a solution of 2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl phenylthiosulfonate 47 (0.70 g, 1.39 mmol) in DCM (10 mL). After stirring overnight, t.l.c. (DCM/methanol, 9:1) showed total consumption of starting material and formation of a major product (R, 0.5). The
reaction mixture was concentrated in vacuo and purified by flash column chromatography (DCM:methanol, 9:1) to afford 21 (240 mg, 62%) as a glassy solid; $[\alpha]_D^{18}$ -58.0 (c, 1 in CHCl$_3$); $\nu_{\text{max}}$ (thin film) 3321 (br, NH) 1749 (s, C=O) 1654 (s, C=O) cm$^{-1}$; $\delta$$_H$ (500 MHz, CDCl$_3$) 1.05 (3H, d, J 6.3 Hz, CH$_3$thr), 1.27 (12H, m, OCH$_2$CH$_3$, C(CH$_3$)$_3$), 1.98, 2.03, 2.04, 2.05 (12H, 4 x s, 4 x C(O)CH$_3$), 2.17 (3H, s, HNC(O)CH$_3$), 3.04 (1H, dd, $J_{\text{CH,H'cys}}$ 14.2 Hz, $J_{\text{CH,H'cys}}$ 8.2 Hz, CH$_3$H'cys), 3.26 (1H, dd, $J_{\text{CH,H'cys}}$ 14.2 Hz, $J_{\text{CH',H''cys}}$ 5.4 Hz, CH$_3$H'cys), 3.85-4.23 (10H, m, H-5, H-6, OCH$_2$CH$_3$, 2 x $\alpha$Hgly, CH$_3$H'thr), 4.40 (1H, dd, J 3.6 Hz, J 6.2 Hz, $\alpha$Hthr), 4.62 (1H, d, $J_{1,2}$ 10.1 Hz, H-1), 4.90 (1H, dd, J 2.5 Hz, J 7.6 Hz, $\alpha$Hcys), 5.10 (1H, dd, $J_{2,3}$ 10.1 Hz, $J_{3,4}$ 3.5 Hz, H-3), 5.38 (1H, at, J 9.9 Hz, H-2), 5.43 (1H, dd, J 0.6 Hz, J 3.5 Hz, H-4), 6.84 (1H, d, J 8.3 Hz, NH), 7.22 (1H, d, J 6.3 Hz, NH), 7.39 (1H, m, NH), 7.64 (1H, at, J 4.8 Hz, NH); $\delta$$_C$ (125.7 MHz, CDCl$_3$) 14.2 (q, OCH$_2$CH$_3$), 17.3 (q, CH$_3$thr), 20.5, 20.6, 20.7, 20.8 (4 x q, 4 x C(O)CH$_3$), 23.1 (q, HNC(O)CH$_3$), 28.1 (q, C(CH$_3$)$_3$), 41.5, 41.7, 43.3 (3 x t, 2 x $\alpha$Cgly, CH$_3$H'cys), 52.5 (d, $\alpha$Ccys), 57.5 (d, $\alpha$Cthr), 61.5 (t, C-6), 66.1, 66.6, 67.4 (3 x d, C-2, C-4, C-5), 71.7 (d, C-3), 75.0 (s, C(CH$_3$)$_3$), 75.6 (t, OCH$_2$CH$_3$), 89.8 (d, C-1), 168.2-170.8 (9 x s, 9 x CO); $m/z$ (ES$^+$) 883 (MMeCNNH$_4^+$, 100%); HRMS (ES$^+$) Calcd. for C$_{33}$H$_{62}$N$_4$NaO$_{16}$S$_2$ (MNa$^+$) 847.2712. Found: 847.2717.
Mechanistic Studies on Desulfurization Reaction

Synthesis of Phenyl 2,3,4,6-tetra-O-benzyl-β-D-glucopyranosyl disulfide 71

![Scheme S20.]

Phenyl 2,3,4,6-tetra-O-benzyl-β-D-glucopyranosyl disulfide 71

A solution of thiophenol (34 µl, 0.34 mmol) in dichloromethane (20 ml) was added dropwise over 45 min to a stirred solution of 2,3,4,6-tetra-O-benzyl-β-D-glucopyranosyl methanethiosulfonate\(^1\) (0.22 g, 0.34 mmol) and triethylamine (47 µl, 0.34 mmol) in dichloromethane (10 ml) at 0 °C. The ice bath was removed. After a further 1 h, t.l.c. (petrol:ethyl acetate, 4:1) showed disappearance of most of the starting material. The reaction mixture was passed through a short silica plug and the plug washed with dichloromethane. The filtrate was evaporated and the residue purified by flash column chromatography (petrol:ethyl acetate, 9:1) to give phenyl 2,3,4,6-tetra-O-benzyl-β-D-glucopyranosyl disulfide 71 (0.12 g, 50%) as a white crystalline solid; m.p. 80-82 °C; \([\alpha]_D^{25}\) -122 (c, 0.7 in CHCl\(_3\)); \(v_{\text{max}}\) (thin film) no significant peaks; \(\delta_H\) (500 MHz, CDCl\(_3\)) 3.48 (1H, m, H-5), 3.66-3.72 (4H, m, H-3, H-4, H-6, H-6'), 3.71 (1H, at, \(J\) 8.7 Hz, H-2), 4.41-4.90 (9H, m, H-1, 4 x OCH\(_2\)Ph), 7.13-7.46 (25H, m, Ar-H); \(\delta_C\) (128.7 MHz, CDCl\(_3\)) 69.0 (t, C-6), 73.6, 75.0, 75.4, 75.7 (4 x t, 4 x OCH\(_2\)Ph), 77.6, 79.5, 80.1 (3 x d, C-2, C-4, C-5), 86.7 (d, C-3), 89.4 (d, C-1), 127.0, 127.5, 127.6, 127.7, 127.8, 127.9, 128.2, 128.3, 128.4, 128.7 (10 x d, Ar-C), 137.4, 137.8, 138.0, 138.2, 138.4 (5 x s, Ar-C); \(m/z\) (ES\(^+\)) 687 (M\(\text{Na}^+\), 100%); HRMS (ES\(^+\)) Calcd. for C\(_{40}\)H\(_{40}\)NaO\(_5\)S\(_2\) (M\(\text{Na}^+)\) 687.2209. Found: 687.2212.
Phenyl 2,3,4,6-tetra-O-benzyl-1-thio-α-D-glucopyranoside 72

Tributylphosphine (44 µl, 0.18 mmol) was added to a stirred solution of phenyl 2,3,4,6-tetra-O-benzyl-β-D-glucopyranosyl disulfide 71 (59 mg, 0.09 mmol) in anhydrous dichloromethane (2 ml) under an atmosphere of argon. After 5 h, t.l.c. (petrol:ethyl acetate, 8:2) showed incomplete consumption of the starting material along with the formation of two products. A further portion of tributylphosphine (44 µl, 0.18 mmol) was added and the reaction mixture stirred for 12 h. The solvent was removed in vacuo and the resulting residue purified by flash column chromatography (petrol:ethyl acetate, 8:2) to afford phenyl 2,3,4,6-tetra-O-benzyl-1-thio-α-D-glucopyranoside 72 (7 mg, 12%) as a white foam and 2,3,4,6-tetra-O-benzyl-1-thio-β-D-glucopyranose 73 (35 mg, 72%) as an oil being a mixture of anomers (α:β, 1:2);

Phenyl 2,3,4,6-tetra-O-benzyl-1-thio-α-D-glucopyranoside\(^{17}\) 72: \([\alpha]_D^{20} +124 \text{ (c, 1 in CHCl}_3\) [Lit. \([\alpha]_D^{25} +128.2 \text{ (c, 1 in CHCl}_3\)]\(^{17}\); \(\delta_H\) (500 MHz, CDCl\(_3\)) 3.59 (1H, dd, \(J_{5,6}\) 2.0 Hz, \(J_{6,\beta}\) 10.8 Hz, H-6), 3.70-3.76 (2H, m, H-4, H-6\(^\beta\)), 3.93 (1H, at, \(J 9.0\) Hz, H-3), 3.99 (1H, dd, \(J_{1,2}\) 4.7 Hz, \(J_{2,3}\) 9.5 Hz, H-2), 4.28 (1H, ddd, \(J_{4,5}\) 10.0 Hz, \(J_{5,6}\) 1.8 Hz, \(J_{5,\beta}\) 3.6 Hz, H-5), 4.43-4.87 (8H, m, 4 x OCH\(_2\)Ph), 5.66 (1H, d, \(J_{1,2}\) 4.8 Hz, H-1), 7.17-7.45 (25H, m, Ar-H); \(m/z\) (ES\(^+\)) 650 (MNH\(_4^+\), 80%) 655 (MNa\(^+\), 100%).

2,3,4,6-Tetra-O-benzyl-1-thio-β-D-glucopyranose\(^{21}\) 73: m.p. 48-50 °C (ether/petrol) [Lit. 47-50 °C\(^{22}\); \([\alpha]_D^{25} +42.5 \text{ (c, 0.75 in CHCl}_3\)]\(^{22}\); \(\delta_H\) (500 MHz, CDCl\(_3\)) 1.95 (1H, d, \(J_{1,\beta}\) 4.8 Hz, SH\(\alpha\)), 2.37 (1H, d, \(J_{1,\beta}\) 8.1 Hz, SH\(\beta\)), 3.43 (1H, at, \(J 9.0\) Hz, H-2\(\beta\)), 3.50-3.58 (1H, m, H-5\(\beta\)), 3.67-3.73 (2H, m, H-3\(\alpha\), H-3\(\beta\)), 3.78-3.88 (6H, m, H-4\(\alpha\), H-6\(\alpha\), H-6\(\beta\), H-4\(\beta\), H-6\(\beta\), H-6\(\beta\)), 3.92 (1H, dd, \(J_{1,2}\) 4.9 Hz, \(J_{2,3}\) 9.0 Hz, H-2\(\alpha\)), 4.25-4.28 (1H, m, H-5\(\alpha\)), 4.56 (1H, dd, \(J_{1,\beta}\) 8.1 Hz, \(J_{1,2}\) 9.0 Hz, H-1\(\beta\)), 4.57-5.01 (16H, m, 4 x OCH\(_2\)Ph\(\alpha\), 4 x OCH\(_2\)Ph\(\beta\)), 5.80 (1H, at, \(J 4.8\) Hz, H-1\(\alpha\)), 7.19-7.43 (40H, m, 20 x Ar-H\(\alpha\), 20 x Ar-H\(\beta\)); \(m/z\) (ES\(^+\)) 574 (MNH\(_4^+\), 100%) 579 (MNa\(^+\), 80%).
Crossover experiment

Preparation of \(N\)-(tert-Butoxycarbonyl)-L-cysteine methyl ester\(^{23}\) \(\text{74}\)

Methanol (100 mL) was added to a flame dried 250 mL round bottom flask equipped with a teflon stir bar. The solvent was stirred and cooled to 0 °C and acetyl chloride (17.6 mL, 248 mmol) was added dropwise over 5 minutes. The solution was stirred an additional 10 minutes at 0 °C to give a concentrated solution of HCl-L-cysteine (2\(\alpha\).00 g, 16.51 mmol) was then added in one portion and the flask flushed with argon. The ice bath was removed and the reaction was stirred at room temperature for 24 h. The solvent was then removed under reduced pressure to give the crude cysteine methyl ester hydrochloride as a pale yellow solid. This material was used immediately in the next step without purification. The crude ester was suspended in dichloromethane (100 mL) and cooled to 0 °C. Triethylamine (5.06 mL, 36.3 mmol) was added carefully followed by di-tert-butyl dicarbonate (4.32 g, 19.81 mmol). The reaction was stirred at room temperature for 3.25 h after which time t.l.c. (ethyl acetate:petrol, 3:7) revealed the desired product (R\(_f\) 0.6) and its corresponding disulfide (R\(_f\) 0.3). The solvent was removed under reduced pressure and the resulting residue was redissolved in methanol (40 mL) and water (8 mL). Tributylphosphine (2.0 mL, 8.1 mmol) was added dropwise to the stirred solution. t.l.c. revealed reduction of the disulfide. The reaction was diluted with diethyl ether (100 mL) and water (50 mL). The organic layer was separated and the aqueous layer was extracted with diethyl ether (2 \(\times\) 50 mL). The combined organics were washed with brine (100 mL), dried over MgSO\(_4\), and filtered. The solvent was removed by rotary evaporation and the residue purified by column chromatography eluting first with 5% ethyl acetate in petrol and then 20% ethyl acetate in petrol. The titled compound \(\text{74}\) was isolated as a clear oil (3.48 g, 89% from L-cysteine); [\(\alpha\)]\(^{20}\)\(_D\) +28.3 (c = 7.5, CHCl\(_3\)) [Lit. [\(\alpha\)]\(^{20}\)\(_D\) +28.5 (c, 7.5 in CHCl\(_3\))\(^{23}\); \(\delta\)\(_H\) (400 MHz, CDCl\(_3\)) 1.42 (10H, s, SH, C(CH\(_3\))\(_3\)), 2.94 (2H, atd, J 4.3 Hz, J 8.7 Hz, CH\(_2\)SH), 3.76 (3H, s, CO\(_2\)CH\(_3\)), 4.58 (1H, m, \(\alpha\)H), 5.44 (1H, d, J 5.8 Hz, NH); \(\delta\)\(_C\) (100.7 MHz, CDCl\(_3\)) 27.3 (t, CH\(_2\)SH), 28.2 (q, C(CH\(_3\))\(_3\)), 52.6 (q,
Synthesis of \(N\)-(tert-butoxycarbonyl)-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-\(\beta\)-D-glucopyranosyl disulfide) methyl ester 75

2,3,4,6-Tetra-O-acetyl-\(\beta\)-D-glucopyranosyl phenylthiosulfonate 42 (200 mg, 0.397 mmol) was dissolved in anhydrous DCM (8 mL) and stirred at room temperature under an atmosphere of argon. A solution of \(N\)-(tert-butoxycarbonyl)-L-cysteine methyl ester 74 (93 mg, 0.397 mmol) and triethylamine (55 \(\mu\)L, 0.397 mmol) in a mixture of anhydrous DCM (10 mL) and anhydrous methanol (2 mL) was slowly added via a syringe pump over a 2 h period. After 1 h, t.l.c. (petrol:ethyl acetate, 1:1) indicated the formation of a product (R\(_f\) 0.5) along with complete consumption of the starting material (R\(_f\) 0.4). The reaction mixture was concentrated in vacuo and the resulting residue purified by flash column chromatography (ethyl acetate:petrol, 1:2) to afford \(N\)-(tert-butoxycarbonyl)-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-\(\beta\)-D-glucopyranosyl disulfide) methyl ester 75 (155 mg, 66%) as a white amorphous solid; \(\alpha\)\(\text{D}\) 22\(^\circ\) +105 (c, 1 in CHCl\(\text{3}\)); \(\nu\)\(_{\text{max}}\) (KBr disc) 3416 (br, NH) 1750 (s, C=O) cm\(^{-1}\); \(\delta\)\(_{\text{H}}\) (400 MHz, CDCl\(\text{3}\)) 1.46 (9H, s, C(CH\(\text{3}\))\(_3\)), 2.01, 2.03, 2.04, 2.09 (12H, 4 x s, 4 x C(O)CH\(\text{3}\)), 3.06 (1H, dd, \(J\)\(_{\text{CH,CH}}\) 13.8 Hz, \(J\)\(_{\text{CH,CH}}\) 7.7 Hz, \(\text{CH,CH}\)), 3.31 (1H, dd, \(J\)\(_{\text{CH,CH}}\) 13.9 Hz, \(J\)\(_{\text{CH',CH'}}\) 4.7 Hz, \(\text{CH',CH'}\)), 3.77 (3H, s, OCH\(\text{3}\)), 3.80 (1H, m, H-5), 4.16 (1H, dd, \(J\)\(_{5.6,6'}\) 2.1 Hz, \(J\)\(_{6.6'}\) 12.4 Hz, H-6), 4.27 (1H, dd, \(J\)\(_{5.6,6'}\) 4.6 Hz, \(J\)\(_{5.6,6'}\) 12.4 Hz, H-6'), 4.57 (1H, d, \(J\)\(_{1.2}\) 9.3 Hz, H-1), 4.68 (1H, m, \(\alpha\)H), 5.14 (1H, at, \(J\) 9.7 Hz,
H-4), 5.24-5.34 (2H, m, H-2, H-3); δ C (100.7 MHz, CDCl$_3$) 20.6, 20.7, 20.8 (3 x q, 4 x C(O)CH$_3$), 28.3 (q, C(CH$_3$)$_3$), 42.6 (t, CH$_2$H'), 52.6 (d, αC), 52.8 (q, OCH$_3$), 61.9 (t, C-6), 67.8 (d, C-4), 68.9 (d, C-2), 73.8 (d, C-3), 76.1 (d, C-5), 80.3 (s, C(CH$_3$)$_3$), 87.8 (d, C-1), 169.2, 169.4, 170.2, 170.6 (4 x s, 4 x C(O)CH$_3$, CO$_2$CH$_3$); m/z (ES$^+$) 615 (MNH$_4^+$, 100%), 620 (MNa$^+$, 95%); HRMS (ES$^+$) Calcd. for C$_{23}$H$_{35}$NNaO$_{13}$S$_2$ (MNa$^+$) 620.1451. Found: 6201451.

Scheme S23. Crossover experiment.

N-Acetyl-L-cysteine (2,3,4,6-tetra-O-benzyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 3 (12 mg, 17 µmol) and N-(tert-butoxycarbonyl)-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 75 (10 mg, 17 µmol) was dissolved in degassed anhydrous methanol (0.5 mL). Hexamethylphosphorus (7 µL, 37 µmol) was added via microsyringe, and the resulting solution stirred under an atmosphere of argon. The reaction was analysed directly by ESI mass spectrometry and distinct peaks were observed for 77 and 78.
ESI (negative mode) after 1.5 h:

NMR kinetics on desulfurization reaction

N-Acetyl-L-cysteine (2,3,4,6-tetra-O-benzyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 3 (20 mg, 27 µmol) was dissolved in degassed deuterated methanol (0.5 mL) in a precision NMR tube. Hexamethyolphosphorus triamide (11 µL, 62 µmol) was added via microsyringe, and the resulting solution placed in a Bruker AV II 500 spectrometer at 30
°C equipped with a triple resonance (TBI) inverse probe. The $^1$H NMR spectra were collected at 6 minute intervals which included 1 minute data acquisition. Integrated peak intensities were analysed as a function of the reaction time course.

Figure S5. $^1$H-NMR before (A) and immediately (B) after addition of HMPT.

The spectroscopic data for the dehydroalanine intermediate (δ 5.86 and 6.31 ppm) was identical to that previously reported in the literature.24

Figure S6. Formation and consumption of dehydroalanine during the desulfurization reaction.
Figure S7. Plot of $^1$H NMR signal intensities (relative to those in the first spectrum) showing the kinetics of the consumption of dehydroalanine.
References


Spectral Data for all new compounds

*p*-Nitrophenyl 2,3,4,6-tetra-\( \text{O} \)-benzyl-1-thio-\( \alpha \)-\( \text{d} \)-glucopyranoside 2

![Chemical structure of the compound](image)
$N$-Acetyl-DL-cysteine-$S$-(2,3,4,6-tetra-$O$-benzyl-$\beta$-$D$-glucopyranoside)

methyl ester 4
$N$-Acetyl-DL-cysteine-$S$-(2,3,4-tri-$O$-benzyl-$1$-thio-$\alpha$-$L$-fucopyranoside)

methylester 6
$N$-Acetyl-DL-cysteine-$S$-(2,3,4,6-tetra-$O$-acetyl-$\beta$-$D$-glucopyranoside) methylester 8
$N$-Acetyl-$dL$-cysteinamide-$S$(2,3,4,6-tetra-$O$-acetyl-$\beta$-$D$-glucopyranoside) 10
$N$-Acetyl-DL-cysteine-$S$(2,3,4,6-tetra-$O$-acetyl-$\beta$-$D$-galactopyranoside)
methylester 12
$N$-Acetyl-DL-cysteine-S-(3,4,6-tetra-$O$-acetyl-2-acetamido-2-deoxy-$\beta$-$D$-glucopyranoside) methylester 14
N-Acetyl-DL-cysteine-S(β-D-glucopyranoside) methylester 16
N-Acetyl-DL-cysteine-S-(2-acetamido-2-deoxy-β-D-glucopyranoside) methylester 18
$N$-Acetyl-$DL$-cysteine-$S$(2,3,4,6-tetra-$O$-acetyl-$\beta$-$D$-glucopyranoside)$-O$-$tert$-butyl-$L$-serine-glycine ethylester 20
$N$-Acetyl-DL-cysteine-$S$-(2,3,4,6-tetra-$O$-acetyl-$\beta$-$D$-galactopyranoside)-glycine-$O$-tert-butyl-$L$-serine-glycine ethylester 22
$N$-Acetyl-$L$-cysteine (2,3,4,6-tetra-$O$-benzyl-1-dithio-$\beta$-$D$-glucopyranosyl disulfide) methylester 3
2,3,4-Tri-\(O\)-benzyl-\(\alpha\)-L-fucopyranosyl phenylthiosulfonate 38
$N$-Acetyl-$L$-cysteine (2,3,4-tri-$O$-benzyl-1-dithio-$\alpha$-$L$-fucopyranosyl disulfide) methylester 5
$N$-Acetyl-$L$-cysteine (2,3,4,6-tetra-$O$-acetyl-1-dithio-$\beta$-$D$-glucopyranosyl disulfide) methylester 7
$N$-Acetyl-$\text{-l}$-cysteinamide (2,3,4,6-tetra-$O$-acetyl-1-dithio-$\beta$-$D$-glucopyranosyl disulfide) 9
\[ N\text{-Acetyl-L-cysteine} \quad (2,3,4,6\text{-tetra-O-acetyl-1-dithio-}\beta\text{-D-galactopyranosyl disulfide) methylester 11} \]
$N$-Acetyl-$L$-cysteine (3,4,6-tetra-$O$-acetyl-2-acetamido-2-deoxy-1-dithio-$\beta$-$D$-glucopyranosyl disulfide) methylester 13
**N-Acetyl-L-cysteine (1-dithio-β-ᴅ-glucopyranosyl disulfide) methylester 15**

![Chemical structure diagram](image)
$N$-Acetyl-$L$-cysteine (2-acetamido-2-deoxy-1-dithio-$\beta$-$D$-glucopyranosyl disulfide) methylester 17
N-fluorenly methoxycarbonyl- O-tert-butyl-L-serine-glycine ethyl ester 59
$N$-fluorenyl methoxycarbonyl-$S$-trityl-$L$-cysteine-$O$-tert-buty-$L$-serine-$glycine$

ethyl ester 60
$S$-trityl-$L$-cysteine-$O$-tert-butyl-$L$-serine-glycine ethyl ester 61

\[
\begin{align*}
H_2N & \quad \text{O} \\
\text{TrS} & \quad \text{O} \\
\text{O}Bu & \quad \text{OEt}
\end{align*}
\]
N-acetyl-S-trityl-L-cysteine-O-tert-butyl-L-serine-glycine ethyl ester 62
$N$-fluorenly methoxycarbonyl-L-threonine-glycine ethyl ester 64
$N$-fluorenyl methoxycarbonyl-glycine-$O$-tert-butyl-$L$-threonine-glycine ethyl ester 65
$N$-fluorenyl methoxycarbonyl-$S$-trityl-$L$-cysteine-$O$-tert-butyl-$L$-threonine-$L$-glycine ethyl ester 67
$N$-acetyl-$S$-trityl-$L$-cysteine-$O$-tert-butyl-$L$-threonine-$L$-glycine ethyl ester
N-acetyl-L-cysteine-glycine-O-tert-butyl-L-threonine-glycine ethyl ester 63
$N$-Acetyl-L-cysteine-(2,3,4,6-tetra-O-acetyl-1-dithio-$\beta$-D-glucopyranosyl disulfide)-O-$\textit{tert}$-butyl-L-serine-glycine ethyl ester 19
**N-Acetyl-L-cysteine-(2,3,4,6-tetra-O-acetyl-1-dithio-β-D-galactopyranosyl)-glycine-O-tert-butyl-L-threonine-glycine ethyl ester 21**
$N$-(tert-butoxycarbonyl)-L-cysteine (2,3,4,6-tetra-O-acetyl-1-dithio-β-D-glucopyranosyl disulfide) methyl ester 75