

1. Aas, F.E., Vik, A., Vedde, J., Koomey, M. and Egge-Jacobsen, W. (2007) *Neisseria gonorrhoeae* O-linked pilin glycosylation: functional analyses define both the biosynthetic pathway and glycan structure. *Mol Microbiol*, **65**, 607-624.
2. Abu-Qarn, M. and Eichler, J. (2006) Protein N-glycosylation in Archaea: defining *Haloferax volcanii* genes involved in S-layer glycoprotein glycosylation. *Mol Microbiol*, **61**, 511-525.
3. Abu-Qarn, M., Eichler, J. and Sharon, N. (2008) Not just for Eukarya anymore: protein glycosylation in Bacteria and Archaea. *Curr Opin Struct Biol*, **18**, 544-550.
4. Abu-Qarn, M., Giordano, A., Battaglia, F., Trauner, A., Hitchen, P.G., Morris, H.R., Dell, A. and Eichler, J. (2008) Identification of AglE, a second glycosyltransferase involved in N glycosylation of the *Haloferax volcanii* S-layer glycoprotein. *J Bacteriol*, **190**, 3140-3146.
5. Abu-Qarn, M., Yurist-Doutsch, S., Giordano, A., Trauner, A., Morris, H.R., Hitchen, P., Medalia, O., Dell, A. and Eichler, J. (2007) *Haloferax volcanii* AglB and AglD are involved in N-glycosylation of the S-layer glycoprotein and proper assembly of the surface layer. *J Mol Biol*, **374**, 1224-1236.
6. Arora, S.K., Bangera, M., Lory, S. and Ramphal, R. (2001) A genomic island in *Pseudomonas aeruginosa* carries the determinants of flagellin glycosylation. *Proc Natl Acad Sci U S A*, **98**, 9342-9347.
7. Arora, S.K., Wolfgang, M.C., Lory, S. and Ramphal, R. (2004) Sequence polymorphism in the glycosylation island and flagellins of *Pseudomonas aeruginosa*. *J Bacteriol*, **186**, 2115-2122.
8. Bartels, K.M., Funken, H., Knapp, A., Brocker, M., Bott, M., Wilhelm, S., Jaeger, K.E. and Rosenau, F. Glycosylation is required for outer membrane localization of the lectin LecB in *Pseudomonas aeruginosa*. *J Bacteriol*, **193**, 1107-1113.
9. Bayley, D.P. and Jarrell, K.F. (1999) Overexpression of *Methanococcus voltae* flagellin subunits in *Escherichia coli* and *Pseudomonas aeruginosa*: a source of archaeal preflagellin. *J Bacteriol*, **181**, 4146-4153.
10. Benz, I. and Schmidt, M.A. (2001) Glycosylation with heptose residues mediated by the *aah* gene product is essential for adherence of the AIDA-I adhesin. *Mol Microbiol*, **40**, 1403-1413.
11. Benz, I. and Schmidt, M.A. (2002) Never say never again: protein glycosylation in pathogenic bacteria. *Mol Microbiol*, **45**, 267-276.
12. Brimer, C.D. and Montie, T.C. (1998) Cloning and comparison of *fliC* genes and identification of glycosylation in the flagellin of *Pseudomonas aeruginosa* a-type strains. *J Bacteriol*, **180**, 3209-3217.
13. Brockl, G., Behr, M., Fabry, S., Hensel, R., Kaudewitz, H., Biendl, E. and Konig, H. (1991) Analysis and nucleotide sequence of the genes encoding the surface-layer glycoproteins of the hyperthermophilic methanogens *Methanothermus fervidus* and *Methanothermus sociabilis*. *Eur J Biochem*, **199**, 147-152.
14. Calo, D., Kaminski, L. and Eichler, J. Protein glycosylation in Archaea: sweet and extreme. *Glycobiology*, **20**, 1065-1076.
15. Castric, P. (1995) *pilO*, a gene required for glycosylation of *Pseudomonas aeruginosa* 1244 pilin. *Microbiology*, **141** (Pt 5), 1247-1254.
16. Castric, P., Cassels, F.J. and Carlson, R.W. (2001) Structural characterization of the *Pseudomonas aeruginosa* 1244 pilin glycan. *J Biol Chem*, **276**, 26479-26485.

17. Chaban, B., Logan, S.M., Kelly, J.F. and Jarrell, K.F. (2009) AglC and AglK are involved in biosynthesis and attachment of diacetylated glucuronic acid to the N-glycan in *Methanococcus voltae*. *J Bacteriol*, **191**, 187-195.
18. Chaban, B., Voisin, S., Kelly, J., Logan, S.M. and Jarrell, K.F. (2006) Identification of genes involved in the biosynthesis and attachment of *Methanococcus voltae* N-linked glycans: insight into N-linked glycosylation pathways in Archaea. *Mol Microbiol*, **61**, 259-268.
19. Chamot-Rooke, J., Rousseau, B., Lanternier, F., Mikaty, G., Mairey, E., Malosse, C., Bouchoux, G., Pelicic, V., Camoin, L., Nassif, X. *et al.* (2007) Alternative *Neisseria* spp. type IV pilin glycosylation with a glyceramido acetamido trideoxyhexose residue. *Proc Natl Acad Sci U S A*, **104**, 14783-14788.
20. Charbonneau, M.E., Girard, V., Nikolakakis, A., Campos, M., Berthiaume, F., Dumas, F., Lepine, F. and Mourez, M. (2007) O-linked glycosylation ensures the normal conformation of the autotransporter adhesin involved in diffuse adherence. *J Bacteriol*, **189**, 8880-8889.
21. Che, F.S., Nakajima, Y., Tanaka, N., Iwano, M., Yoshida, T., Takayama, S., Kadota, I. and Isogai, A. (2000) Flagellin from an incompatible strain of *Pseudomonas avenae* induces a resistance response in cultured rice cells. *J Biol Chem*, **275**, 32347-32356.
22. Choi, K.J., Grass, S., Paek, S., St Geme, J.W., 3rd and Yeo, H.J. The *Actinobacillus pleuropneumoniae* HMW1C-like glycosyltransferase mediates N-linked glycosylation of the *Haemophilus influenzae* HMW1 adhesin. *PLoS One*, **5**, e15888.
23. Christian, R., Schulz, G., Unger, F.M., Messner, P., Kupcu, Z. and Sleytr, U.B. (1986) Structure of a rhamnan from the surface-layer glycoprotein of *Bacillus stearothermophilus* strain NRS 2004/3a. *Carbohydr Res*, **150**, 265-272.
24. Cohen-Krausz, S. and Trachtenberg, S. (2002) The structure of the archaeobacterial flagellar filament of the extreme halophile *Halobacterium salinarum* R1M1 and its relation to eubacterial flagellar filaments and type IV pili. *J Mol Biol*, **321**, 383-395.
25. Comer, J.E., Marshall, M.A., Blanch, V.J., Deal, C.D. and Castric, P. (2002) Identification of the *Pseudomonas aeruginosa* 1244 pilin glycosylation site. *Infect Immun*, **70**, 2837-2845.
26. Cooper, H.N., Gurcha, S.S., Nigou, J., Brennan, P.J., Belisle, J.T., Besra, G.S. and Young, D. (2002) Characterization of mycobacterial protein glycosyltransferase activity using synthetic peptide acceptors in a cell-free assay. *Glycobiology*, **12**, 427-434.
27. Craig, L., Volkmann, N., Arvai, A.S., Pique, M.E., Yeager, M., Egelman, E.H. and Tainer, J.A. (2006) Type IV pilus structure by cryo-electron microscopy and crystallography: implications for pilus assembly and functions. *Mol Cell*, **23**, 651-662.
28. Davis, B.G., Lloyd, R.C. and Jones, J.B. (2000) Controlled site-selective protein glycosylation for precise glycan structure-catalytic activity relationships. *Bioorg Med Chem*, **8**, 1527-1535.
29. Davis, L.M., Kakuda, T. and DiRita, V.J. (2009) A *Campylobacter jejuni* znuA orthologue is essential for growth in low-zinc environments and chick

- colonization. *J Bacteriol*, **191**, 1631-1640.
30. de Vos, W.M., Voorhorst, W.G., Dijkgraaf, M., Kluskens, L.D., Van der Oost, J. and Siezen, R.J. (2001) Purification, characterization, and molecular modeling of pyrolysins and other extracellular thermostable serine proteases from hyperthermophilic microorganisms. *Methods Enzymol*, **330**, 383-393.
 31. Dell, A., Galadari, A., Sastre, F. and Hitchen, P. Similarities and differences in the glycosylation mechanisms in prokaryotes and eukaryotes. *Int J Microbiol*, **2010**, 148178.
 32. DiGiandomenico, A., Matewish, M.J., Bisailon, A., Stehle, J.R., Lam, J.S. and Castric, P. (2002) Glycosylation of *Pseudomonas aeruginosa* 1244 pilin: glycan substrate specificity. *Mol Microbiol*, **46**, 519-530.
 33. Dobos, K.M., Khoo, K.H., Swiderek, K.M., Brennan, P.J. and Belisle, J.T. (1996) Definition of the full extent of glycosylation of the 45-kilodalton glycoprotein of *Mycobacterium tuberculosis*. *J Bacteriol*, **178**, 2498-2506.
 34. Dobos, K.M., Swiderek, K., Khoo, K.H., Brennan, P.J. and Belisle, J.T. (1995) Evidence for glycosylation sites on the 45-kilodalton glycoprotein of *Mycobacterium tuberculosis*. *Infect Immun*, **63**, 2846-2853.
 35. Doig, P., Kinsella, N., Guerry, P. and Trust, T.J. (1996) Characterization of a post-translational modification of *Campylobacter* flagellin: identification of a sero-specific glycosyl moiety. *Mol Microbiol*, **19**, 379-387.
 36. Eichler, J. (2000) Novel glycoproteins of the halophilic archaeon *Haloferax volcanii*. *Arch Microbiol*, **173**, 445-448.
 37. Eichler, J. and Adams, M.W. (2005) Posttranslational protein modification in Archaea. *Microbiol Mol Biol Rev*, **69**, 393-425.
 38. Espitia, C., Espinosa, R., Saavedra, R., Mancilla, R., Romain, F., Laqueyrie, A. and Moreno, C. (1995) Antigenic and structural similarities between *Mycobacterium tuberculosis* 50- to 55-kilodalton and *Mycobacterium bovis* BCG 45- to 47-kilodalton antigens. *Infect Immun*, **63**, 580-584.
 39. Espitia, C. and Mancilla, R. (1989) Identification, isolation and partial characterization of *Mycobacterium tuberculosis* glycoprotein antigens. *Clin Exp Immunol*, **77**, 378-383.
 40. Espitia, C., Servin-Gonzalez, L. and Mancilla, R. New insights into protein O-mannosylation in actinomycetes. *Mol Biosyst*, **6**, 775-781.
 41. Ewing, C.P., Andreishcheva, E. and Guerry, P. (2009) Functional characterization of flagellin glycosylation in *Campylobacter jejuni* 81-176. *J Bacteriol*, **191**, 7086-7093.
 42. Fethiere, J., Eggimann, B. and Cygler, M. (1999) Crystal structure of chondroitin AC lyase, a representative of a family of glycosaminoglycan degrading enzymes. *J Mol Biol*, **288**, 635-647.
 43. Fifis, T., Costopoulos, C., Radford, A.J., Bacic, A. and Wood, P.R. (1991) Purification and characterization of major antigens from a *Mycobacterium bovis* culture filtrate. *Infect Immun*, **59**, 800-807.
 44. Fletcher, C.M., Coyne, M.J. and Comstock, L.E. Theoretical and experimental characterization of the scope of protein O-glycosylation in *Bacteroides fragilis*. *J Biol Chem*, **286**, 3219-3226.
 45. Fletcher, C.M., Coyne, M.J., Villa, O.F., Chatzidaki-Livanis, M. and Comstock,

- L.E. (2009) A general O-glycosylation system important to the physiology of a major human intestinal symbiont. *Cell*, **137**, 321-331.
46. Forest, K.T., Dunham, S.A., Koomey, M. and Tainer, J.A. (1999) Crystallographic structure reveals phosphorylated pilin from *Neisseria*: phosphoserine sites modify type IV pilus surface chemistry and fibre morphology. *Mol Microbiol*, **31**, 743-752.
47. Gerl, L., Deutzmann, R. and Sumper, M. (1989) Halobacterial flagellins are encoded by a multigene family. Identification of all five gene products. *FEBS Lett*, **244**, 137-140.
48. Gerl, L. and Sumper, M. (1988) Halobacterial flagellins are encoded by a multigene family. Characterization of five flagellin genes. *J Biol Chem*, **263**, 13246-13251.
49. Glover, K.J., Weerapana, E., Numao, S. and Imperiali, B. (2005) Chemoenzymatic synthesis of glycopeptides with PglB, a bacterial oligosaccharyl transferase from *Campylobacter jejuni*. *Chem Biol*, **12**, 1311-1315.
50. Godavarti, R. and Sasisekharan, R. (1996) A comparative analysis of the primary sequences and characteristics of heparinases I, II, and III from *Flavobacterium heparinum*. *Biochem Biophys Res Commun*, **229**, 770-777.
51. Goon, S., Kelly, J.F., Logan, S.M., Ewing, C.P. and Guerry, P. (2003) Pseudaminic acid, the major modification on *Campylobacter* flagellin, is synthesized via the Cj1293 gene. *Mol Microbiol*, **50**, 659-671.
52. Grass, S., Buscher, A.Z., Swords, W.E., Apicella, M.A., Barenkamp, S.J., Ozchlewski, N. and St Geme, J.W., 3rd. (2003) The *Haemophilus influenzae* HMW1 adhesin is glycosylated in a process that requires HMW1C and phosphoglucomutase, an enzyme involved in lipooligosaccharide biosynthesis. *Mol Microbiol*, **48**, 737-751.
53. Grass, S., Lichti, C.F., Townsend, R.R., Gross, J. and St Geme, J.W., 3rd. The *Haemophilus influenzae* HMW1C protein is a glycosyltransferase that transfers hexose residues to asparagine sites in the HMW1 adhesin. *PLoS Pathog*, **6**, e1000919.
54. Graycar, T., Knapp, M., Ganshaw, G., Dauberman, J. and Bott, R. (1999) Engineered *Bacillus lentus* subtilisins having altered flexibility. *J Mol Biol*, **292**, 97-109.
55. Grogan, D.W. (1989) Phenotypic characterization of the archaeobacterial genus *Sulfolobus*: comparison of five wild-type strains. *J Bacteriol*, **171**, 6710-6719.
56. Gross, J., Grass, S., Davis, A.E., Gilmore-Erdmann, P., Townsend, R.R. and St Geme, J.W., 3rd. (2008) The *Haemophilus influenzae* HMW1 adhesin is a glycoprotein with an unusual N-linked carbohydrate modification. *J Biol Chem*, **283**, 26010-26015.
57. Guerry, P., Doig, P., Alm, R.A., Burr, D.H., Kinsella, N. and Trust, T.J. (1996) Identification and characterization of genes required for post-translational modification of *Campylobacter coli* VC167 flagellin. *Mol Microbiol*, **19**, 369-378.
58. Hahn, M., Keitel, T. and Heinemann, U. (1995) Crystal and molecular structure at 0.16-nm resolution of the hybrid *Bacillus endo*-1,3-1,4-beta-D-glucan 4-glucanohydrolase H(A16-M). *Eur J Biochem*, **232**, 849-858.
59. Hahn, M., Piotukh, K., Borriss, R. and Heinemann, U. (1994) Native-like in vivo folding of a circularly permuted jellyroll protein shown by crystal structure

- analysis. *Proc Natl Acad Sci U S A*, **91**, 10417-10421.
60. Hegge, F.T., Hitchen, P.G., Aas, F.E., Kristiansen, H., Lovold, C., Egge-Jacobsen, W., Panico, M., Leong, W.Y., Bull, V., Virji, M. *et al.* (2004) Unique modifications with phosphocholine and phosphoethanolamine define alternate antigenic forms of *Neisseria gonorrhoeae* type IV pili. *Proc Natl Acad Sci U S A*, **101**, 10798-10803.
 61. Herrmann, J.L., Delahay, R., Gallagher, A., Robertson, B. and Young, D. (2000) Analysis of post-translational modification of mycobacterial proteins using a cassette expression system. *FEBS Lett*, **473**, 358-362.
 62. Hettmann, T., Schmidt, C.L., Anemuller, S., Zahringer, U., Moll, H., Petersen, A. and Schafer, G. (1998) Cytochrome b558/566 from the archaeon *Sulfolobus acidocaldarius*. A novel highly glycosylated, membrane-bound b-type hemoprotein. *J Biol Chem*, **273**, 12032-12040.
 63. Hirai, H., Takai, R., Iwano, M., Nakai, M., Kondo, M., Takayama, S., Isogai, A. and Che, F.S. Glycosylation regulates the specific induction of rice immune responses by *Acidovorax avenae* flagellin. *J Biol Chem*.
 64. Horn, C., Namane, A., Pescher, P., Riviere, M., Romain, F., Puzo, G., Barzu, O. and Marchal, G. (1999) Decreased capacity of recombinant 45/47-kDa molecules (Apa) of *Mycobacterium tuberculosis* to stimulate T lymphocyte responses related to changes in their mannosylation pattern. *J Biol Chem*, **274**, 32023-32030.
 65. Horzempa, J., Dean, C.R., Goldberg, J.B. and Castric, P. (2006) *Pseudomonas aeruginosa* 1244 pilin glycosylation: glycan substrate recognition. *J Bacteriol*, **188**, 4244-4252.
 66. Huang, W., Boju, L., Tkalec, L., Su, H., Yang, H.O., Gunay, N.S., Linhardt, R.J., Kim, Y.S., Matte, A. and Cygler, M. (2001) Active site of chondroitin AC lyase revealed by the structure of enzyme-oligosaccharide complexes and mutagenesis. *Biochemistry*, **40**, 2359-2372.
 67. Huang, W., Lunin, V.V., Li, Y., Suzuki, S., Sugiura, N., Miyazono, H. and Cygler, M. (2003) Crystal structure of *Proteus vulgaris* chondroitin sulfate ABC lyase I at 1.9 Å resolution. *J Mol Biol*, **328**, 623-634.
 68. Huang, W., Matte, A., Li, Y., Kim, Y.S., Linhardt, R.J., Su, H. and Cygler, M. (1999) Crystal structure of chondroitinase B from *Flavobacterium heparinum* and its complex with a disaccharide product at 1.7 Å resolution. *J Mol Biol*, **294**, 1257-1269.
 69. Igura, M. and Kohda, D. Selective control of oligosaccharide transfer efficiency for the N-glycosylation sequon by a point mutation in oligosaccharyltransferase. *J Biol Chem*, **286**, 13255-13260.
 70. Igura, M., Maita, N., Kamishikiryo, J., Yamada, M., Obita, T., Maenaka, K. and Kohda, D. (2008) Structure-guided identification of a new catalytic motif of oligosaccharyltransferase. *EMBO J*, **27**, 234-243.
 71. Jarrell, K.F., Jones, G.M. and Nair, D.B. Biosynthesis and role of N-linked glycosylation in cell surface structures of archaea with a focus on flagella and s layers. *Int J Microbiol*, **2010**, 470138.
 72. Jennings, M.P., Jen, F.E., Roddam, L.F., Apicella, M.A. and Edwards, J.L. *Neisseria gonorrhoeae* pilin glycan contributes to CR3 activation during

- challenge of primary cervical epithelial cells. *Cell Microbiol*, **13**, 885-896.
73. Josenhans, C., Vossebein, L., Friedrich, S. and Suerbaum, S. (2002) The neuA/flmD gene cluster of Helicobacter pylori is involved in flagellar biosynthesis and flagellin glycosylation. *FEMS Microbiol Lett*, **210**, 165-172.
 74. Kahlig, H., Kolarich, D., Zayni, S., Scheberl, A., Kosma, P., Schaffer, C. and Messner, P. (2005) N-acetylmuramic acid as capping element of alpha-D-fucose-containing S-layer glycoprotein glycans from Geobacillus tepidamans GS5-97T. *J Biol Chem*, **280**, 20292-20299.
 75. Kakuda, T. and DiRita, V.J. (2006) Cj1496c encodes a Campylobacter jejuni glycoprotein that influences invasion of human epithelial cells and colonization of the chick gastrointestinal tract. *Infect Immun*, **74**, 4715-4723.
 76. Kalmokoff, M.L., Koval, S.F. and Jarrell, K.F. (1992) Relatedness of the flagellins from methanogens. *Arch Microbiol*, **157**, 481-487.
 77. Kaminski, L., Abu-Qarn, M., Guan, Z., Naparstek, S., Ventura, V.V., Raetz, C.R., Hitchen, P.G., Dell, A. and Eichler, J. AglJ adds the first sugar of the N-linked pentasaccharide decorating the Haloferax volcanii S-layer glycoprotein. *J Bacteriol*, **192**, 5572-5579.
 78. Kaminski, L. and Eichler, J. Identification of residues important for the activity of Haloferax volcanii AglD, a component of the archaeal N-glycosylation pathway. *Archaea*, **2010**, 315108.
 79. Karcher, U., Schroder, H., Haslinger, E., Allmaier, G., Schreiner, R., Wieland, F., Haselbeck, A. and Konig, H. (1993) Primary structure of the heterosaccharide of the surface glycoprotein of Methanothermus fervidus. *J Biol Chem*, **268**, 26821-26826.
 80. Keitel, T., Meldgaard, M. and Heinemann, U. (1994) Cation binding to a Bacillus (1,3-1,4)-beta-glucanase. Geometry, affinity and effect on protein stability. *Eur J Biochem*, **222**, 203-214.
 81. Kelly, J., Logan, S.M., Jarrell, K.F., VanDyke, D.J. and Vinogradov, E. (2009) A novel N-linked flagellar glycan from Methanococcus maripaludis. *Carbohydr Res*, **344**, 648-653.
 82. Kneidinger, B., Graninger, M., Puchberger, M., Kosma, P. and Messner, P. (2001) Biosynthesis of nucleotide-activated D-glycero-D-manno-heptose. *J Biol Chem*, **276**, 20935-20944.
 83. Knudsen, S.K., Stensballe, A., Franzmann, M., Westergaard, U.B. and Otzen, D.E. (2008) Effect of glycosylation on the extracellular domain of the Ag43 bacterial autotransporter: enhanced stability and reduced cellular aggregation. *Biochem J*, **412**, 563-577.
 84. Konishi, T., Taguchi, F., Iwaki, M., Ohnishi-Kameyama, M., Yamamoto, M., Maeda, I., Nishida, Y., Ichinose, Y., Yoshida, M. and Ishii, T. (2009) Structural characterization of an O-linked tetrasaccharide from Pseudomonas syringae pv. tabaci flagellin. *Carbohydr Res*, **344**, 2250-2254.
 85. Kosma, P., Neuninger, C., Christian, R., Schulz, G. and Messner, P. (1995) Glycan structure of the S-layer glycoprotein of Bacillus sp. L420-91. *Glycoconj J*, **12**, 99-107.
 86. Kosma, P., Wugeditsch, T., Christian, R., Zayni, S. and Messner, P. (1995) Glycan structure of a heptose-containing S-layer glycoprotein of Bacillus

- thermoaerophilus. *Glycobiology*, **5**, 791-796.
87. Kowarik, M., Young, N.M., Numao, S., Schulz, B.L., Hug, I., Callewaert, N., Mills, D.C., Watson, D.C., Hernandez, M., Kelly, J.F. *et al.* (2006) Definition of the bacterial N-glycosylation site consensus sequence. *EMBO J*, **25**, 1957-1966.
 88. Kupcu, Z., Marz, L., Messner, P. and Sleytr, U.B. (1984) Evidence for the glycoprotein nature of the crystalline cell wall surface layer of *Bacillus stearothermophilus* strain NRS2004/3a. *FEBS Lett*, **173**, 185-190.
 89. Kus, J.V., Kelly, J., Tessier, L., Harvey, H., Cvitkovitch, D.G. and Burrows, L.L. (2008) Modification of *Pseudomonas aeruginosa* Pa5196 type IV Pilins at multiple sites with D-Araf by a novel GT-C family Arabinosyltransferase, TfpW. *J Bacteriol*, **190**, 7464-7478.
 90. Kus, J.V., Tullis, E., Cvitkovitch, D.G. and Burrows, L.L. (2004) Significant differences in type IV pilin allele distribution among *Pseudomonas aeruginosa* isolates from cystic fibrosis (CF) versus non-CF patients. *Microbiology*, **150**, 1315-1326.
 91. Lara, M., Servin-Gonzalez, L., Singh, M., Moreno, C., Cohen, I., Nimtz, M. and Espitia, C. (2004) Expression, secretion, and glycosylation of the 45- and 47-kDa glycoprotein of *Mycobacterium tuberculosis* in *Streptomyces lividans*. *Appl Environ Microbiol*, **70**, 679-685.
 92. Larsen, J.C., Szymanski, C. and Guerry, P. (2004) N-linked protein glycosylation is required for full competence in *Campylobacter jejuni* 81-176. *J Bacteriol*, **186**, 6508-6514.
 93. Lechner, J. and Sumper, M. (1987) The primary structure of a procaryotic glycoprotein. Cloning and sequencing of the cell surface glycoprotein gene of halobacteria. *J Biol Chem*, **262**, 9724-9729.
 94. Lechner, J., Wieland, F. and Sumper, M. (1985) Transient methylation of dolichyl oligosaccharides is an obligatory step in halobacterial sulfated glycoprotein biosynthesis. *J Biol Chem*, **260**, 8984-8989.
 95. Lechner, J., Wieland, F. and Sumper, M. (1985) Biosynthesis of sulfated saccharides N-glycosidically linked to the protein via glucose. Purification and identification of sulfated dolichyl monophosphoryl tetrasaccharides from halobacteria. *J Biol Chem*, **260**, 860-866.
 96. Lin, X. and Tang, J. (1990) Purification, characterization, and gene cloning of thermopsin, a thermostable acid protease from *Sulfolobus acidocaldarius*. *J Biol Chem*, **265**, 1490-1495.
 97. Linton, D., Allan, E., Karlyshev, A.V., Cronshaw, A.D. and Wren, B.W. (2002) Identification of N-acetylgalactosamine-containing glycoproteins PEB3 and CgpA in *Campylobacter jejuni*. *Mol Microbiol*, **43**, 497-508.
 98. Linton, D., Karlyshev, A.V., Hitchen, P.G., Morris, H.R., Dell, A., Gregson, N.A. and Wren, B.W. (2000) Multiple N-acetyl neuraminic acid synthetase (neuB) genes in *Campylobacter jejuni*: identification and characterization of the gene involved in sialylation of lipo-oligosaccharide. *Mol Microbiol*, **35**, 1120-1134.
 99. Lloyd, R.C., Davis, B.G. and Jones, J.B. (2000) Site-selective glycosylation of subtilisin *Bacillus lentus* causes dramatic increases in esterase activity. *Bioorg Med Chem*, **8**, 1537-1544.
 100. Logan, S.M. (2006) Flagellar glycosylation - a new component of the motility

- repertoire? *Microbiology*, **152**, 1249-1262.
101. Logan, S.M., Hui, J.P., Vinogradov, E., Aubry, A.J., Melanson, J.E., Kelly, J.F., Nothaft, H. and Soo, E.C. (2009) Identification of novel carbohydrate modifications on *Campylobacter jejuni* 11168 flagellin using metabolomics-based approaches. *FEBS J*, **276**, 1014-1023.
 102. Logan, S.M., Kelly, J.F., Thibault, P., Ewing, C.P. and Guerry, P. (2002) Structural heterogeneity of carbohydrate modifications affects serospecificity of *Campylobacter* flagellins. *Mol Microbiol*, **46**, 587-597.
 103. Logan, S.M., Trust, T.J. and Guerry, P. (1989) Evidence for posttranslational modification and gene duplication of *Campylobacter* flagellin. *J Bacteriol*, **171**, 3031-3038.
 104. Lupas, A., Engelhardt, H., Peters, J., Santarius, U., Volker, S. and Baumeister, W. (1994) Domain structure of the *Acetogenium kivui* surface layer revealed by electron crystallography and sequence analysis. *J Bacteriol*, **176**, 1224-1233.
 105. Magidovich, H., Yurist-Doutsch, S., Konrad, Z., Ventura, V.V., Dell, A., Hitchen, P.G. and Eichler, J. AgIP is a S-adenosyl-L-methionine-dependent methyltransferase that participates in the N-glycosylation pathway of *Haloferax volcanii*. *Mol Microbiol*, **76**, 190-199.
 106. Maita, N., Nyirenda, J., Igura, M., Kamishikiryo, J. and Kohda, D. Comparative structural biology of eubacterial and archaeal oligosaccharyltransferases. *J Biol Chem*, **285**, 4941-4950.
 107. Marceau, M., Forest, K., Beretti, J.L., Tainer, J. and Nassif, X. (1998) Consequences of the loss of O-linked glycosylation of meningococcal type IV pilin on piliation and pilus-mediated adhesion. *Mol Microbiol*, **27**, 705-715.
 108. McNally, D.J., Aubry, A.J., Hui, J.P., Khieu, N.H., Whitfield, D., Ewing, C.P., Guerry, P., Brisson, J.R., Logan, S.M. and Soo, E.C. (2007) Targeted metabolomics analysis of *Campylobacter coli* VC167 reveals legionaminic acid derivatives as novel flagellar glycans. *J Biol Chem*, **282**, 14463-14475.
 109. McNally, D.J., Hui, J.P., Aubry, A.J., Mui, K.K., Guerry, P., Brisson, J.R., Logan, S.M. and Soo, E.C. (2006) Functional characterization of the flagellar glycosylation locus in *Campylobacter jejuni* 81-176 using a focused metabolomics approach. *J Biol Chem*, **281**, 18489-18498.
 110. Mengele, R. and Sumper, M. (1992) Drastic differences in glycosylation of related S-layer glycoproteins from moderate and extreme halophiles. *J Biol Chem*, **267**, 8182-8185.
 111. Mescher, M.F. and Strominger, J.L. (1976) Purification and characterization of a prokaryotic glucoprotein from the cell envelope of *Halobacterium salinarium*. *J Biol Chem*, **251**, 2005-2014.
 112. Mescher, M.F., Strominger, J.L. and Watson, S.W. (1974) Protein and carbohydrate composition of the cell envelope of *Halobacterium salinarium*. *J Bacteriol*, **120**, 945-954.
 113. Messner, P. (1997) Bacterial glycoproteins. *Glycoconj J*, **14**, 3-11.
 114. Messner, P. and Schaffer, C. (2003) Prokaryotic glycoproteins. *Fortschr Chem Org Naturst*, **85**, 51-124.
 115. Messner, P., Steiner, K., Zarschler, K. and Schaffer, C. (2008) S-layer nanoglycobiology of bacteria. *Carbohydr Res*, **343**, 1934-1951.

116. Michel, G., Pojasek, K., Li, Y., Sulea, T., Linhardt, R.J., Raman, R., Prabhakar, V., Sasisekharan, R. and Cygler, M. (2004) The structure of chondroitin B lyase complexed with glycosaminoglycan oligosaccharides unravels a calcium-dependent catalytic machinery. *J Biol Chem*, **279**, 32882-32896.
117. Michell, S.L., Whelan, A.O., Wheeler, P.R., Panico, M., Easton, R.L., Etienne, A.T., Haslam, S.M., Dell, A., Morris, H.R., Reason, A.J. *et al.* (2003) The MPB83 antigen from *Mycobacterium bovis* contains O-linked mannose and (1->3)-mannobiose moieties. *J Biol Chem*, **278**, 16423-16432.
118. Miller, W.L., Matewish, M.J., McNally, D.J., Ishiyama, N., Anderson, E.M., Brewer, D., Brisson, J.R., Berghuis, A.M. and Lam, J.S. (2008) Flagellin glycosylation in *Pseudomonas aeruginosa* PAK requires the O-antigen biosynthesis enzyme WbpO. *J Biol Chem*, **283**, 3507-3518.
119. Moormann, C., Benz, I. and Schmidt, M.A. (2002) Functional substitution of the TibC protein of enterotoxigenic *Escherichia coli* strains for the autotransporter adhesin heptosyltransferase of the AIDA system. *Infect Immun*, **70**, 2264-2270.
120. Muir, E.M., Fyfe, I., Gardiner, S., Li, L., Warren, P., Fawcett, J.W., Keynes, R.J. and Rogers, J.H. Modification of N-glycosylation sites allows secretion of bacterial chondroitinase ABC from mammalian cells. *J Biotechnol*, **145**, 103-110.
121. Nita-Lazar, M., Wacker, M., Schegg, B., Amber, S. and Aebi, M. (2005) The N-X-S/T consensus sequence is required but not sufficient for bacterial N-linked protein glycosylation. *Glycobiology*, **15**, 361-367.
122. Nothhaft, H. and Szymanski, C.M. Protein glycosylation in bacteria: sweeter than ever. *Nat Rev Microbiol*, **8**, 765-778.
123. Novotny, R., Schaffer, C., Strauss, J. and Messner, P. (2004) S-layer glycan-specific loci on the chromosome of *Geobacillus stearothermophilus* NRS 2004/3a and dTDP-L-rhamnose biosynthesis potential of *G. stearothermophilus* strains. *Microbiology*, **150**, 953-965.
124. Olivier, N.B., Chen, M.M., Behr, J.R. and Imperiali, B. (2006) In vitro biosynthesis of UDP-N,N'-diacetylbacillosamine by enzymes of the *Campylobacter jejuni* general protein glycosylation system. *Biochemistry*, **45**, 13659-13669.
125. Oman, T.J., Boettcher, J.M., Wang, H., Okalibe, X.N. and van der Donk, W.A. Sublancin is not a lantibiotic but an S-linked glycopeptide. *Nat Chem Biol*, **7**, 78-80.
126. Ozbek, S., Muller, J.F., Figgemeier, E. and Stetefeld, J. (2005) Favourable mediation of crystal contacts by cocoamidopropylbetaine (CAPB). *Acta Crystallogr D Biol Crystallogr*, **61**, 477-480.
127. Parge, H.E., Forest, K.T., Hickey, M.J., Christensen, D.A., Getzoff, E.D. and Tainer, J.A. (1995) Structure of the fibre-forming protein pilin at 2.6 Å resolution. *Nature*, **378**, 32-38.
128. Paul, G., Lottspeich, F. and Wieland, F. (1986) Asparaginyln-acetylgalactosamine. Linkage unit of halobacterial glycosaminoglycan. *J Biol Chem*, **261**, 1020-1024.
129. Peters, J., Baumeister, W. and Lupas, A. (1996) Hyperthermostable surface layer protein tetrabrachion from the archaeobacterium *Staphylothermus marinus*: evidence for the presence of a right-handed coiled coil derived from the primary structure. *J Mol Biol*, **257**, 1031-1041.

130. Peters, J., Nitsch, M., Kuhlmoorgen, B., Golbik, R., Lupas, A., Kellermann, J., Engelhardt, H., Pfander, J.P., Muller, S., Goldie, K. *et al.* (1995) Tetrabrachion: a filamentous archaebacterial surface protein assembly of unusual structure and extreme stability. *J Mol Biol*, **245**, 385-401.
131. Peters, J., Rudolf, S., Oschkinat, H., Mengele, R., Sumper, M., Kellermann, J., Lottspeich, F. and Baumeister, W. (1992) Evidence for tyrosine-linked glycosaminoglycan in a bacterial surface protein. *Biol Chem Hoppe Seyler*, **373**, 171-176.
132. Peyfoon, E., Meyer, B., Hitchen, P.G., Panico, M., Morris, H.R., Haslam, S.M., Albers, S.V. and Dell, A. The S-layer glycoprotein of the crenarchaeote *Sulfolobus acidocaldarius* is glycosylated at multiple sites with chitobiose-linked N-glycans. *Archaea*, **2010**.
133. Pfoestl, A., Hofinger, A., Kosma, P. and Messner, P. (2003) Biosynthesis of dTDP-3-acetamido-3,6-dideoxy-alpha-D-galactose in *Aneurinibacillus thermoaerophilus* L420-91T. *J Biol Chem*, **278**, 26410-26417.
134. Plavner, N. and Eichler, J. (2008) Defining the topology of the N-glycosylation pathway in the halophilic archaeon *Haloferax volcanii*. *J Bacteriol*, **190**, 8045-8052.
135. Plummer, T.H., Jr., Tarentino, A.L. and Hauer, C.R. (1995) Novel, specific O-glycosylation of secreted *Flavobacterium meningosepticum* proteins. Asp-Ser and Asp-Thr-Thr consensus sites. *J Biol Chem*, **270**, 13192-13196.
136. Power, P.M., Roddam, L.F., Dieckelmann, M., Srikhanta, Y.N., Tan, Y.C., Berrington, A.W. and Jennings, M.P. (2000) Genetic characterization of pilin glycosylation in *Neisseria meningitidis*. *Microbiology*, **146 (Pt 4)**, 967-979.
137. Power, P.M., Seib, K.L. and Jennings, M.P. (2006) Pilin glycosylation in *Neisseria meningitidis* occurs by a similar pathway to wzy-dependent O-antigen biosynthesis in *Escherichia coli*. *Biochem Biophys Res Commun*, **347**, 904-908.
138. Rangarajan, E.S., Bhatia, S., Watson, D.C., Munger, C., Cygler, M., Matte, A. and Young, N.M. (2007) Structural context for protein N-glycosylation in bacteria: The structure of PEB3, an adhesin from *Campylobacter jejuni*. *Protein Sci*, **16**, 990-995.
139. Reinhold, B.B., Hauer, C.R., Plummer, T.H. and Reinhold, V.N. (1995) Detailed structural analysis of a novel, specific O-linked glycan from the prokaryote *Flavobacterium meningosepticum*. *J Biol Chem*, **270**, 13197-13203.
140. Ristl, R., Steiner, K., Zarschler, K., Zayni, S., Messner, P. and Schaffer, C. The S-layer glycome-adding to the sugar coat of bacteria. *Int J Microbiol*, **2011**.
141. Romain, F., Horn, C., Pescher, P., Namane, A., Riviere, M., Puzo, G., Barzu, O. and Marchal, G. (1999) Deglycosylation of the 45/47-kilodalton antigen complex of *Mycobacterium tuberculosis* decreases its capacity to elicit in vivo or in vitro cellular immune responses. *Infect Immun*, **67**, 5567-5572.
142. Santos-Silva, T., Dias, J.M., Dolla, A., Durand, M.C., Goncalves, L.L., Lampreia, J., Moura, I. and Romao, M.J. (2007) Crystal structure of the 16 heme cytochrome from *Desulfovibrio gigas*: a glycosylated protein in a sulphate-reducing bacterium. *J Mol Biol*, **370**, 659-673.
143. Sartain, M.J. and Belisle, J.T. (2009) N-Terminal clustering of the O-glycosylation sites in the *Mycobacterium tuberculosis* lipoprotein SodC. *Glycobiology*, **19**, 38-

- 51.
144. Sasisekharan, R., Bulmer, M., Moremen, K.W., Cooney, C.L. and Langer, R. (1993) Cloning and expression of heparinase I gene from *Flavobacterium heparinum*. *Proc Natl Acad Sci U S A*, **90**, 3660-3664.
 145. Schaffer, C. and Messner, P. (2004) Surface-layer glycoproteins: an example for the diversity of bacterial glycosylation with promising impacts on nanobiotechnology. *Glycobiology*, **14**, 31R-42R.
 146. Schaffer, C., Muller, N., Christian, R., Graninger, M., Wugeditsch, T., Scheberl, A. and Messner, P. (1999) Complete glycan structure of the S-layer glycoprotein of *Aneurinibacillus thermoaerophilus* GS4-97. *Glycobiology*, **9**, 407-414.
 147. Schaffer, C., Wugeditsch, T., Kahlig, H., Scheberl, A., Zayni, S. and Messner, P. (2002) The surface layer (S-layer) glycoprotein of *Geobacillus stearothermophilus* NRS 2004/3a. Analysis of its glycosylation. *J Biol Chem*, **277**, 6230-6239.
 148. Scherman, H., Kaur, D., Pham, H., Skovierova, H., Jackson, M. and Brennan, P.J. (2009) Identification of a polyprenylphosphomannosyl synthase involved in the synthesis of mycobacterial mannosides. *J Bacteriol*, **191**, 6769-6772.
 149. Schirm, M., Arora, S.K., Verma, A., Vinogradov, E., Thibault, P., Ramphal, R. and Logan, S.M. (2004) Structural and genetic characterization of glycosylation of type a flagellin in *Pseudomonas aeruginosa*. *J Bacteriol*, **186**, 2523-2531.
 150. Schirm, M., Kalmokoff, M., Aubry, A., Thibault, P., Sandoz, M. and Logan, S.M. (2004) Flagellin from *Listeria monocytogenes* is glycosylated with beta-O-linked N-acetylglucosamine. *J Bacteriol*, **186**, 6721-6727.
 151. Schirm, M., Soo, E.C., Aubry, A.J., Austin, J., Thibault, P. and Logan, S.M. (2003) Structural, genetic and functional characterization of the flagellin glycosylation process in *Helicobacter pylori*. *Mol Microbiol*, **48**, 1579-1592.
 152. Schmidt, M.A., Riley, L.W. and Benz, I. (2003) Sweet new world: glycoproteins in bacterial pathogens. *Trends Microbiol*, **11**, 554-561.
 153. Schoenhofen, I.C., Lunin, V.V., Julien, J.P., Li, Y., Ajamian, E., Matte, A., Cygler, M., Brisson, J.R., Aubry, A., Logan, S.M. *et al.* (2006) Structural and functional characterization of PseC, an aminotransferase involved in the biosynthesis of pseudaminic acid, an essential flagellar modification in *Helicobacter pylori*. *J Biol Chem*, **281**, 8907-8916.
 154. Schwarz, F., Lizak, C., Fan, Y.Y., Fleurkens, S., Kowarik, M. and Aebi, M. Relaxed acceptor site specificity of bacterial oligosaccharyltransferase in vivo. *Glycobiology*, **21**, 45-54.
 155. Scott, N.E., Bogema, D.R., Connolly, A.M., Falconer, L., Djordjevic, S.P. and Cordwell, S.J. (2009) Mass spectrometric characterization of the surface-associated 42 kDa lipoprotein JlpA as a glycosylated antigen in strains of *Campylobacter jejuni*. *J Proteome Res*, **8**, 4654-4664.
 156. Shams-Eldin, H., Chaban, B., Niehus, S., Schwarz, R.T. and Jarrell, K.F. (2008) Identification of the archaeal alg7 gene homolog (encoding N-acetylglucosamine-1-phosphate transferase) of the N-linked glycosylation system by cross-domain complementation in *Saccharomyces cerevisiae*. *J Bacteriol*, **190**, 2217-2220.
 157. Shaya, D., Tocilj, A., Li, Y., Myette, J., Venkataraman, G., Sasisekharan, R. and Cygler, M. (2006) Crystal structure of heparinase II from *Pedobacter heparinus*

- and its complex with a disaccharide product. *J Biol Chem*, **281**, 15525-15535.
158. Sherlock, O., Dobrindt, U., Jensen, J.B., Munk Vejborg, R. and Klemm, P. (2006) Glycosylation of the self-recognizing Escherichia coli Ag43 autotransporter protein. *J Bacteriol*, **188**, 1798-1807.
 159. Sherlock, O., Schembri, M.A., Reisner, A. and Klemm, P. (2004) Novel roles for the AIDA adhesin from diarrheagenic Escherichia coli: cell aggregation and biofilm formation. *J Bacteriol*, **186**, 8058-8065.
 160. Smedley, J.G., 3rd, Jewell, E., Roguskie, J., Horzempa, J., Syboldt, A., Stolz, D.B. and Castric, P. (2005) Influence of pilin glycosylation on Pseudomonas aeruginosa 1244 pilus function. *Infect Immun*, **73**, 7922-7931.
 161. Spagnolo, L., Toro, I., D'Orazio, M., O'Neill, P., Pedersen, J.Z., Carugo, O., Rotilio, G., Battistoni, A. and Djinovic-Carugo, K. (2004) Unique features of the sodC-encoded superoxide dismutase from Mycobacterium tuberculosis, a fully functional copper-containing enzyme lacking zinc in the active site. *J Biol Chem*, **279**, 33447-33455.
 162. Steiner, K., Novotny, R., Patel, K., Vinogradov, E., Whitfield, C., Valvano, M.A., Messner, P. and Schaffer, C. (2007) Functional characterization of the initiation enzyme of S-layer glycoprotein glycan biosynthesis in Geobacillus stearothermophilus NRS 2004/3a. *J Bacteriol*, **189**, 2590-2598.
 163. Steiner, K., Novotny, R., Werz, D.B., Zarschler, K., Seeberger, P.H., Hofinger, A., Kosma, P., Schaffer, C. and Messner, P. (2008) Molecular basis of S-layer glycoprotein glycan biosynthesis in Geobacillus stearothermophilus. *J Biol Chem*, **283**, 21120-21133.
 164. Steiner, K., Pohlentz, G., Dreisewerd, K., Berkenkamp, S., Messner, P., Peter-Katalinic, J. and Schaffer, C. (2006) New insights into the glycosylation of the surface layer protein SgsE from Geobacillus stearothermophilus NRS 2004/3a. *J Bacteriol*, **188**, 7914-7921.
 165. Stepper, J., Shastri, S., Loo, T.S., Preston, J.C., Novak, P., Man, P., Moore, C.H., Havlicek, V., Patchett, M.L. and Norris, G.E. Cysteine S-glycosylation, a new post-translational modification found in glycopeptide bacteriocins. *FEBS Lett*, **585**, 645-650.
 166. Stetefeld, J., Jenny, M., Schulthess, T., Landwehr, R., Engel, J. and Kammerer, R.A. (2000) Crystal structure of a naturally occurring parallel right-handed coiled coil tetramer. *Nat Struct Biol*, **7**, 772-776.
 167. Stimson, E., Virji, M., Makepeace, K., Dell, A., Morris, H.R., Payne, G., Saunders, J.R., Jennings, M.P., Barker, S., Panico, M. *et al.* (1995) Meningococcal pilin: a glycoprotein substituted with digalactosyl 2,4-diacetamido-2,4,6-trideoxyhexose. *Mol Microbiol*, **17**, 1201-1214.
 168. Sugiyama, S., Matsuo, Y., Maenaka, K., Vassylyev, D.G., Matsushima, M., Kashiwagi, K., Igarashi, K. and Morikawa, K. (1996) The 1.8-Å X-ray structure of the Escherichia coli PotD protein complexed with spermidine and the mechanism of polyamine binding. *Protein Sci*, **5**, 1984-1990.
 169. Sugiyama, S., Vassylyev, D.G., Matsushima, M., Kashiwagi, K., Igarashi, K. and Morikawa, K. (1996) Crystal structure of PotD, the primary receptor of the polyamine transport system in Escherichia coli. *J Biol Chem*, **271**, 9519-9525.
 170. Sumper, M., Berg, E., Mengele, R. and Strobel, I. (1990) Primary structure and

- glycosylation of the S-layer protein of *Haloferax volcanii*. *J Bacteriol*, **172**, 7111-7118.
171. Szymanski, C.M., Burr, D.H. and Guerry, P. (2002) Campylobacter protein glycosylation affects host cell interactions. *Infect Immun*, **70**, 2242-2244.
 172. Szymanski, C.M. and Wren, B.W. (2005) Protein glycosylation in bacterial mucosal pathogens. *Nat Rev Microbiol*, **3**, 225-237.
 173. Taguchi, F., Shimizu, R., Inagaki, Y., Toyoda, K., Shiraishi, T. and Ichinose, Y. (2003) Post-translational modification of flagellin determines the specificity of HR induction. *Plant Cell Physiol*, **44**, 342-349.
 174. Taguchi, F., Takeuchi, K., Katoh, E., Murata, K., Suzuki, T., Marutani, M., Kawasaki, T., Eguchi, M., Katoh, S., Kaku, H. *et al.* (2006) Identification of glycosylation genes and glycosylated amino acids of flagellin in *Pseudomonas syringae* pv. *tabaci*. *Cell Microbiol*, **8**, 923-938.
 175. Taguchi, F., Yamamoto, M., Ohnishi-Kameyama, M., Iwaki, M., Yoshida, M., Ishii, T., Konishi, T. and Ichinose, Y. Defects in flagellin glycosylation affect the virulence of *Pseudomonas syringae* pv. *tabaci* 6605. *Microbiology*, **156**, 72-80.
 176. Takeuchi, K., Ono, H., Yoshida, M., Ishii, T., Katoh, E., Taguchi, F., Miki, R., Murata, K., Kaku, H. and Ichinose, Y. (2007) Flagellin glycans from two pathovars of *Pseudomonas syringae* contain rhamnose in D and L configurations in different ratios and modified 4-amino-4,6-dideoxyglucose. *J Bacteriol*, **189**, 6945-6956.
 177. Tarentino, A.L., Quinones, G., Changchien, L.M. and Plummer, T.H., Jr. (1993) Multiple endoglycosidase F activities expressed by *Flavobacterium meningosepticum* endoglycosidases F2 and F3. Molecular cloning, primary sequence, and enzyme expression. *J Biol Chem*, **268**, 9702-9708.
 178. Tarentino, A.L., Quinones, G., Grimwood, B.G., Hauer, C.R. and Plummer, T.H., Jr. (1995) Molecular cloning and sequence analysis of flavastacin: an O-glycosylated prokaryotic zinc metalloendopeptidase. *Arch Biochem Biophys*, **319**, 281-285.
 179. Thibault, P., Logan, S.M., Kelly, J.F., Brisson, J.R., Ewing, C.P., Trust, T.J. and Guerry, P. (2001) Identification of the carbohydrate moieties and glycosylation motifs in *Campylobacter jejuni* flagellin. *J Biol Chem*, **276**, 34862-34870.
 180. Totten, P.A. and Lory, S. (1990) Characterization of the type a flagellin gene from *Pseudomonas aeruginosa* PAK. *J Bacteriol*, **172**, 7188-7199.
 181. Twine, S.M., Paul, C.J., Vinogradov, E., McNally, D.J., Brisson, J.R., Mullen, J.A., McMullin, D.R., Jarrell, H.C., Austin, J.W., Kelly, J.F. *et al.* (2008) Flagellar glycosylation in *Clostridium botulinum*. *FEBS J*, **275**, 4428-4444.
 182. Twine, S.M., Reid, C.W., Aubry, A., McMullin, D.R., Fulton, K.M., Austin, J. and Logan, S.M. (2009) Motility and flagellar glycosylation in *Clostridium difficile*. *J Bacteriol*, **191**, 7050-7062.
 183. Upreti, R.K., Kumar, M. and Shankar, V. (2003) Bacterial glycoproteins: functions, biosynthesis and applications. *Proteomics*, **3**, 363-379.
 184. VanDyke, D.J., Wu, J., Logan, S.M., Kelly, J.F., Mizuno, S., Aizawa, S. and Jarrell, K.F. (2009) Identification of genes involved in the assembly and attachment of a novel flagellin N-linked tetrasaccharide important for motility in the archaeon *Methanococcus maripaludis*. *Mol Microbiol*, **72**, 633-644.

185. VanDyke, D.J., Wu, J., Ng, S.Y., Kanbe, M., Chaban, B., Aizawa, S. and Jarrell, K.F. (2008) Identification of a putative acetyltransferase gene, MMP0350, which affects proper assembly of both flagella and pili in the archaeon *Methanococcus maripaludis*. *J Bacteriol*, **190**, 5300-5307.
186. Veith, A., Klingl, A., Zolghadr, B., Lauber, K., Mentele, R., Lottspeich, F., Rachel, R., Albers, S.V. and Kletzin, A. (2009) Acidianus, Sulfolobus and Metallosphaera surface layers: structure, composition and gene expression. *Mol Microbiol*, **73**, 58-72.
187. Venugopal, H., Edwards, P.J., Schwalbe, M., Claridge, J.K., Libich, D.S., Stepper, J., Loo, T., Patchett, M.L., Norris, G.E. and Pascal, S.M. Structural, dynamic, and chemical characterization of a novel S-glycosylated bacteriocin. *Biochemistry*, **50**, 2748-2755.
188. Verma, A., Schirm, M., Arora, S.K., Thibault, P., Logan, S.M. and Ramphal, R. (2006) Glycosylation of b-Type flagellin of *Pseudomonas aeruginosa*: structural and genetic basis. *J Bacteriol*, **188**, 4395-4403.
189. Vik, A., Aas, F.E., Anonsen, J.H., Bilsborough, S., Schneider, A., Egge-Jacobsen, W. and Koomey, M. (2009) Broad spectrum O-linked protein glycosylation in the human pathogen *Neisseria gonorrhoeae*. *Proc Natl Acad Sci U S A*, **106**, 4447-4452.
190. Vinogradov, E., Perry, M.B. and Kay, W.W. (2003) The structure of the glycopeptides from the fish pathogen *Flavobacterium columnare*. *Carbohydr Res*, **338**, 2653-2658.
191. Virji, M., Saunders, J.R., Sims, G., Makepeace, K., Maskell, D. and Ferguson, D.J. (1993) Pilus-facilitated adherence of *Neisseria meningitidis* to human epithelial and endothelial cells: modulation of adherence phenotype occurs concurrently with changes in primary amino acid sequence and the glycosylation status of pilin. *Mol Microbiol*, **10**, 1013-1028.
192. Virji, M., Stimson, E., Makepeace, K., Dell, A., Morris, H.R., Payne, G., Saunders, J.R. and Moxon, E.R. (1996) Posttranslational modifications of meningococcal pili. Identification of a common trisaccharide substitution on variant pilins of strain C311. *Ann N Y Acad Sci*, **797**, 53-64.
193. Voisin, S., Houlston, R.S., Kelly, J., Brisson, J.R., Watson, D., Bardy, S.L., Jarrell, K.F. and Logan, S.M. (2005) Identification and characterization of the unique N-linked glycan common to the flagellins and S-layer glycoprotein of *Methanococcus voltae*. *J Biol Chem*, **280**, 16586-16593.
194. Voisin, S., Kus, J.V., Houlston, S., St-Michael, F., Watson, D., Cvitkovitch, D.G., Kelly, J., Brisson, J.R. and Burrows, L.L. (2007) Glycosylation of *Pseudomonas aeruginosa* strain Pa5196 type IV pilins with mycobacterium-like alpha-1,5-linked d-Araf oligosaccharides. *J Bacteriol*, **189**, 151-159.
195. Voorhorst, W.G., Eggen, R.I., Geerling, A.C., Platteeuw, C., Siezen, R.J. and Vos, W.M. (1996) Isolation and characterization of the hyperthermostable serine protease, pyrolysin, and its gene from the hyperthermophilic archaeon *Pyrococcus furiosus*. *J Biol Chem*, **271**, 20426-20431.
196. Wacker, M., Linton, D., Hitchen, P.G., Nita-Lazar, M., Haslam, S.M., North, S.J., Panico, M., Morris, H.R., Dell, A., Wren, B.W. et al. (2002) N-linked glycosylation in *Campylobacter jejuni* and its functional transfer into *E. coli*. *Science*, **298**,

- 1790-1793.
197. Waddling, C.A., Plummer, T.H., Jr., Tarentino, A.L. and Van Roey, P. (2000) Structural basis for the substrate specificity of endo-beta-N-acetylglucosaminidase F(3). *Biochemistry*, **39**, 7878-7885.
 198. Wieland, F., Dompert, W., Bernhardt, G. and Sumper, M. (1980) Halobacterial glycoprotein saccharides contain covalently linked sulphate. *FEBS Lett*, **120**, 110-114.
 199. Wieland, F., Heitzer, R. and Schaefer, W. (1983) Asparaginynglucose: Novel type of carbohydrate linkage. *Proc Natl Acad Sci U S A*, **80**, 5470-5474.
 200. Wieland, F., Paul, G. and Sumper, M. (1985) Halobacterial flagellins are sulfated glycoproteins. *J Biol Chem*, **260**, 15180-15185.
 201. Wugeditsch, T., Zachara, N.E., Puchberger, M., Kosma, P., Gooley, A.A. and Messner, P. (1999) Structural heterogeneity in the core oligosaccharide of the S-layer glycoprotein from *Aneurinibacillus thermoaerophilus* DSM 10155. *Glycobiology*, **9**, 787-795.
 202. Yeo, H.J., Yokoyama, T., Walkiewicz, K., Kim, Y., Grass, S. and Geme, J.W., 3rd. (2007) The structure of the *Haemophilus influenzae* HMW1 pro-piece reveals a structural domain essential for bacterial two-partner secretion. *J Biol Chem*, **282**, 31076-31084.
 203. Young, N.M., Brisson, J.R., Kelly, J., Watson, D.C., Tessier, L., Lanthier, P.H., Jarrell, H.C., Cadotte, N., St Michael, F., Aberg, E. *et al.* (2002) Structure of the N-linked glycan present on multiple glycoproteins in the Gram-negative bacterium, *Campylobacter jejuni*. *J Biol Chem*, **277**, 42530-42539.
 204. Yurist-Doutsch, S., Abu-Qarn, M., Battaglia, F., Morris, H.R., Hitchen, P.G., Dell, A. and Eichler, J. (2008) AglF, aglG and aglI, novel members of a gene island involved in the N-glycosylation of the *Haloferax volcanii* S-layer glycoprotein. *Mol Microbiol*, **69**, 1234-1245.
 205. Yurist-Doutsch, S. and Eichler, J. (2009) Manual annotation, transcriptional analysis, and protein expression studies reveal novel genes in the agl cluster responsible for N glycosylation in the halophilic archaeon *Haloferax volcanii*. *J Bacteriol*, **191**, 3068-3075.
 206. Yurist-Doutsch, S., Magidovich, H., Ventura, V.V., Hitchen, P.G., Dell, A. and Eichler, J. N-glycosylation in Archaea: on the coordinated actions of *Haloferax volcanii* AglF and AglM. *Mol Microbiol*, **75**, 1047-1058.
 207. Zahringer, U., Moll, H., Hettmann, T., Knirel, Y.A. and Schafer, G. (2000) Cytochrome b558/566 from the archaeon *Sulfolobus acidocaldarius* has a unique Asn-linked highly branched hexasaccharide chain containing 6-sulfoquinovose. *Eur J Biochem*, **267**, 4144-4149.
 208. Zampronio, C.G., Blackwell, G., Penn, C.W. and Cooper, H.J. Novel Glycosylation Sites Localized in *Campylobacter jejuni* Flagellin FlaA by Liquid Chromatography Electron Capture Dissociation Tandem Mass Spectrometry. *J Proteome Res*, **10**, 1238-1245.
 209. Zayni, S., Steiner, K., Pfohl, A., Hofinger, A., Kosma, P., Schaffer, C. and Messner, P. (2007) The dTDP-4-dehydro-6-deoxyglucose reductase encoding *fcd* gene is part of the surface layer glycoprotein glycosylation gene cluster of *Geobacillus tepidamans* GS5-97T. *Glycobiology*, **17**, 433-443.

210. Zeitler, R., Hochmuth, E., Deutzmann, R. and Sumper, M. (1998) Exchange of Ser-4 for Val, Leu or Asn in the sequon Asn-Ala-Ser does not prevent N-glycosylation of the cell surface glycoprotein from Halobacterium halobium. *Glycobiology*, **8**, 1157-1164.