

REFERENCES

Abraham, S.N., Jonsson, A.B. and Normark, S. 1998. Fimbriae-mediated host-pathogen cross-talk. *Curr. Opin. Microbiol.* **1**: 75-81.

Abraham, S.N., Land, M., Ponniah, S., Endres, R., Hasty, D.L. and Babu, J.P. 1992. Glycerol-induced unraveling of the tight helical conformation of *Escherichia coli* type 1 fimbriae. *J. Bacteriol.* **174**: 5145-5148.

Allison, D.G., Ruiz, B., SanJose, C., Jaspe, A. and Gilbert, P. 1998. Extracellular products as mediators of the formation and detachment of *Pseudomonas fluorescens* biofilms. *FEMS Microbiol. Lett.* **167**: 179-184.

Alm, R.A., Hallinan, J.P., Watson, A.A. and Mattick, J.S. 1996. Fimbrial biogenesis genes of *Pseudomonas aeruginosa*: *pilW* and *pilX* increase the similarity of type 4 fimbriae to the GSP protein secretion systems and *pilY1* encodes a gonococcal PilC homologue. *Mol. Microbiol.* **22**: 161-173.

Alm, R.A., Bandero, A.J., Free, P.D. and Mattick, J.S. 1996. Identification of a novel gene, *pilZ*, essential for type 4 fimbrial biogenesis in *Pseudomonas aeruginosa*. *J. Bacteriol.* **178**: 46-53.

Alm, R.A. and Mattick, J.S. 1995. Identification of a gene, *pilV*, required for type IV fimbrial biogenesis in *Pseudomonas aeruginosa*, whose product possesses a pre-pilin-like leader sequence. *Mol. Microbiol.* **16**: 485-496.

Alm, R.A. and Mattick, J.S. 1996. Identification of two genes with pre pilin-like leader sequences involved in type IV fimbrial biogenesis in *Pseudomonas aeruginosa*. *J. Bacteriol.* **178**: 3809-3817.

Alm, R.S. and Mattick, J.S. 1997. Genes involved in the biogenesis and function of type 4 fimbriae in *Pseudomonas aeruginosa*. *Gene* **192**: 89-98.

Altschul, S.F., Madden, T.L., Schaffer, A.A., Zhang, J., Zhang, Z., Miller, W. and Lipman, D.J. 1997. Gapped BLAST and PSI-BLAST: A new generation of protein database search programs. *Nucl. Acids Res.* **25**: 3389-3402.

Amann, R.I., Krumholz, L. and Stahl, D.A. 1990. Fluorescent-oligonucleotide probing of whole cells for determinative, phylogenetic and environmental studies in microbiology. *J. Bacteriol.* **172**: 762-770.

Amann, R., Snaidr, J., Wagner, M., Ludwig, W. and Schleifer, K.H. 1996. *In situ* visualization of high genetic diversity in a natural microbial community. *J. Bacteriol.* **178**: 3496-3500.

An, Y.H., Dickinson, R.B. and Doyle, R.J. 2000. Mechanisms of bacterial adhesion and pathogenesis of implant and tissue infections. In: *Handbook of Bacterial Adhesion: Principles, Methods and Applications*, pp. 1-27. An, Y.H. and Friedman, R.J. (eds.). Humana Press, Totowa, N.J., USA.

Arnqvist, A., Olsen, A., Pfeifer, J., Russell, D.G. and Normark, S. 1992. The Crl protein activates cryptic genes for curli formation and fibronectin binding in *Escherichia coli* HB101. *Mol. Microbiol.* **6**: 2443-2452.

Austin, J.W., Sanders, G., Kay, W.W. and Collinson, S.K. 1998. Thin aggregative fimbriae enhance *Salmonella enteritidis* biofilm formation. *FEMS Microbiol. Lett.* **162**: 295-301.

Baga, M., Norgren, M. and Normark, S. 1987. Biogenesis of *E. coli* Pap pili: PapH, a minor pilin subunit involved in cell anchoring and length modulation. *Cell* **49**: 241-251.

- Bally, M., Filloux, A., Akrim, M., Ball, G., Lazdunski, A. and Tommassen, J.** 1992. Protein secretion in *Pseudomonas aeruginosa*: Characterization of seven *xcp* genes and processing of secretory apparatus components by prepilin peptidase. *Mol. Microbiol.* **6**: 1121-1131.
- Barnhardt, M.M., Pinker, J.S., Soto, G.E., Sauer, F.G., Langermann, S., Waksman, G., Frieden, C. and Hultgren, S.J.** 2000. PapD-like chaperone provide the missing information for folding of pilin proteins. *Proc. Natl. Acad. Sci. USA* **97**: 7709-7714.
- Beatson, S.A., Whitchurch, C.B., Semmler A.B.T. and Mattick J.S.** 2002. Quorum sensing is not required for twitching motility in *Pseudomonas aeruginosa*. *J. Bacteriol.* **184**: 3598-3604.
- Beveridge, T.J.** 1999. Structures of gram-negative cell walls and their derived membrane vesicles. *J. Bacteriol.* **181**: 4725-4733.
- Bhattacharjee, M.K., Kachlany, S.C., Fine, D.H. and Figurski, D.H.** 2001. Nonspecific adherence and fibril biogenesis by *Actinobacillus actinomycetemcomitans*: TadA protein is an ATPase. *J. Bacteriol.* **183**: 5927-5936.
- Bian, Z., Brauner, A., Li, Y. and Normark, S.** 2000. Expression of and cytokine activation by *Escherichia coli* curli fibers in human sepsis. *J. Infect. Dis.* **181**: 602-612.
- Bian, Z. and Normark, S.** 1997. Nucleator function of CsgB for the assembly of adhesive surface organelles in *Escherichia coli*. *EMBO J.* **16**: 5827-5836.
- Bieber, D., Ramer, S.W., Wu, C.Y., Murray, W.J., Tobe, T., Fernandez, R. and Schoolnik, G.K.** 1998. Type IV pili, transient bacterial aggregates and virulence of enteropathogenic *Escherichia coli*. *Science* **280**: 2114-2118.
- Bitter, W., Koster, M., Latijnhouwers, M., de Cock, H. and Tommassen, J.** 1998. Formation of oligomeric rings by XcpQ and PilQ, which are involved in protein transport across the outer membrane of *Pseudomonas aeruginosa*. *Mol. Microbiol.* **27**: 209-219.
- Blatney, J.M., Brauteset, T., Winther-Larson, H.C., Haugan, K. and Valla, S.** 1997. Construction and use of a versatile set of broad-host-range cloning and expression vectors based on the RK2 replicon. *Appl. Environ. Microbiol.* **63**: 370-379.
- Boland, T., Dufrene, Y., Barger, B. and Lee, G.** 2000. Molecular basis of cell adhesions to polymers characterised AFM. *Crit. Rev. Biomed. Eng.* **28**: 195-196.
- Boland, T., Latour, R.A. and Sutzenberger, F.J.** 2000. Molecular basis of bacterial adhesion. In: *Handbook of Bacterial Adhesion: Principles, Methods and Applications*, pp. 29-41. An, Y.H. and Friedman, R.J. (eds.). Humana Press, Totowa, N.J., USA.
- Boyle, J.S. and Lew, A.M.** 1995. An inexpensive alternative to glassmilk for DNA purification. *TIGS* **11**: 8.
- Bradley, D.E.** 1980. A function of *Pseudomonas aeruginosa* PAO polar pili: Twitching motility. *Can. J. Microbiol.* **26**: 146-154.
- Brinton, C.C.** 1965. The structure, function, synthesis, and genetic control of bacterial pili and a model for DNA and RNA transport in gram-negative bacteria. *Trans. N.Y. Acad. Sci.* **27**: 1003-1065.
- Bullitt, E. and Makowski, L.** 1995. Structural polymorphism of bacterial adhesion pili. *Nature* **373**: 164-167.

- Burns, D.L.** 1999. Biochemistry of type IV secretion. *Curr. Opin. Microbiol.* **2:** 25-29.
- Busby, S. and Ebright, R.H.** 1995. The *Escherichia coli* RNA polymerase alpha subunit: Structure and function. *Curr. Opin. Genet. Dev.* **5:** 197-203.
- Busch, S.J. and Sassone-Corsi, P.** 1990. Dimers, leucine zippers and DNA-binding domains. *TIGS* **6:** 36-40.
- Bush, K.** 1989. Excitement in the beta-lactamase arena. *J. Antimicrob. Chemother.* **24:** 831-836.
- Carpentier, B. and Cerf, O.** 1993. Biofilms and their consequences, with particular references to hygiene in the food industry. *J. Appl. Bacteriol.* **75:** 499-511.
- Chandrasanyal, S. and Liljas, A.** 2000. The end of the beginning: Structural studies of ribosomal protein. *Curr. Opin. Struct. Biol.* **10:** 633-636.
- Choudhury, D., Thompson, A., Stojanoff, V., Langermann, S., Pinker, J., Hultgren, S.J. and Knight, S.D.** 1999. X-ray structure of the FimC-FimH chaperone-adhesin complex from uropathogenic *Escherichia coli*. *Science* **285:** 1061-1066.
- Christie, P.J.** 1997. *Agrobacterium tumefaciens* T-complex transport apparatus: A paradigm for a new family of multifunctional transporters in eubacteria. *J. Bacteriol.* **179:** 3085-3094.
- Christie, P.J.** 2001. Type IV secretion: Intracellular transfer of macromolecules by systems ancestrally related to conjugation machines. *Mol. Microbiol.* **40:** 294-305.
- Chung, C.T. and Miller, R.H.** 1988. A rapid and convenient method for the preparation and storage of competent bacterial cells. *Nucl. Acids Res.* **16:** 3580.
- Cochran, W.L., McFeters, G.A. and Stewart, P.S.** 2000. Reduced susceptibility of thin *Pseudomonas aeruginosa* biofilms to hydrogen peroxide and monochloramine. *J. Appl. Microbiol.* **88:** 22-30.
- Collinson, S.K., Chouthier, S.C., Doran, J.L., Banser, P.A. and Kay, W.W.** *Salmonella enteritidis* ag/BAC operon encoding thin aggregative fimbriae. *J. Bacteriol.* **178:** 662-667.
- Connell, I., Agace, W., Klemm, P., Schembri, M., Marild, S. and Svanborg, C.** 1996. Type 1 fimbrial expression enhances *Escherichia coli* virulence for the urinary tract. *Proc. Natl. Acad. Sci. USA* **93:** 9827-9832.
- Costerton, J.W., Lewandowski, Z., Caldwell, D.E., Korber, D.R. and Lappin-Scott, H.M.** 1995. Microbial biofilms. *Annu. Rev. Microbiol.* **49:** 711-745.
- Costerton, J.W., Stewart, P.S. and Greenberg, E.P.** 1999. Bacterial biofilms: A common cause of persistent infections. *Science* **284:** 1318-1322.
- Danchin, A.** 1997. Comparison between the *Escherichia coli* and *Bacillus subtilis* genomes suggests that a major function of polynucleotide phosphorylase is to synthesize CDP. *DNA Res.* **4:** 9-18.
- Danese, P.N. and Silhavy, T.J.** 1997. The sE and the Cpx signal transduction systems control the synthesis of periplasmic protein-folding systems in *Escherichia coli*. *Genes Dev.* **11:** 1183-1193.
- Darst, S.A. and Zhang, G.** 1998. Structure of the *Escherichia coli* RNA polymerase alpha subunit amino-terminal domain. *Science* **281:** 262-266.

- Darzins, A.** 1993. The *pilG* gene product, required for *Pseudomonas aeruginosa* pilus production and twitching motility, is homologous to the enteric single-domain response regulator CheY. *J. Bacteriol.* **175:** 5934-5944.
- Darzins, A.** 1994. Characterisation of a *Pseudomonas aeruginosa* gene cluster involved in pilus biosynthesis and twitching motility: Sequences similarity to the chemotaxis proteins of enterics and the gliding bacterium *Myxococcus xanthus*. *Mol. Microbiol.* **11:** 137-153.
- Darzins, A.** and **Russell, M.A.** 1997. Molecular genetic analysis of type-4 pilus biogenesis and twitching motility using *Pseudomonas aeruginosa* as a model system - a review. *Gene* **192:** 109-115.
- Das, M., Badley, A.D., Cockerill, F.R., Steckelberg, J.M. and Wilson, W.R.** 1997. Infective endocarditis caused by HACEK microorganisms. *Annu. Rev. Med.* **48:** 25-33.
- Dasgupta, N., Arora, S.K. and Ramphal, R.** 2000. *FleN*, a gene that regulates flagellar numbers in *Pseudomonas aeruginosa*. *J. Bacteriol.* **182:** 357-364.
- Davey, M.E. and O'Toole, G.A.** 2000. Microbial biofilms: From ecology to molecular genetics. *Microbiol. Mol. Biol. Rev.* **64:** 847-867.
- Davies, D.G., Parsek, M.R., Pearson, J.P., Iglewski, B.H., Costerton, J.W. and Greenberg, E.P.** 1998. The involvement of cell-to-cell signals in the development of a bacterial biofilm. *Science* **280:** 295-298.
- DeFlaun, M.F., Oppenheimer, S.R., Streger, S., Condee, C.W. and Fletcher, M.** 1999. Alterations in adhesion, transport, and membrane characteristics in an adhesion-deficient pseudomonad. *Appl. Environ. Microbiol.* **65:** 759-765.
- DeLas, P.A., Connolly, L. and Gross, C.A.** 1997. The oE-mediated response to extracytoplasmic stress in *Escherichia coli* is transduced by RseA and RseB, two negative regulators of oE. *Mol. Microbiol.* **4:** 373-385.
- De Weger, L.A., van der Vlugt, C.I., Wijfjes, A.H., Bakker, P.A., Schippers, B. and Lugtenberg, B.** 1987. Flagella of a plant-growth-stimulating *Pseudomonas fluorescens* strain are required for colonization of potato roots. *J. Bacteriol.* **169:** 2769-2773.
- DiChristina, T.J. and DeLong, E.F.** 1993. Design and application of rRNA-targeted oligonucleotide probes for the dissimilatory iron- and manganese-reducing bacteria. *Appl. Environ. Microbiol.* **59:** 4152-4160.
- Dodson, K.W., Jacob-Dubuisson, F., Striker, R.T. and Hultgren, S.J.** 1993. Outer membrane PapC usher discriminately recognizes periplasmic chaperone-pilus subunit complexes. *Proc. Natl. Acad. Sci. USA* **90:** 3670-3674.
- Doig, P., Todd, T., Sastry, P.A., Lee, K.K., Hodges, R.S., Paranchych, W. and Irvin, R.T.** 1988. Role of pili in adhesion of *Pseudomonas aeruginosa* to human respiratory epithelial cells. *Infect. Immun.* **56:** 1641-1646.
- Donlan, R.M.** 2002. Biofilms: Microbial life on surfaces. *Emerg. Infect. Dis.* **8:** 881-890.
- Drake, S.L. and Koomey, M.** 1995. The product of the *pilQ* gene is essential for the biogenesis of type IV pili in *Neisseria gonorrhoeae*. *Mol. Microbiol.* **18:** 975-986.

- Elkins, J.G., Hassett, D.J., Stewart, P.S., Schweizer, H.P. and McDermott, T.R.** 1999. Protective role of catalase in *Pseudomonas aeruginosa* biofilm resistance to hydrogen peroxide. *Appl. Environ. Microbiol.* **65**: 4594-4600.
- Ensgraber, M. and Loos, M.** 1992. A 66-kilodalton heat shock protein of *Salmonella typhimurium* is responsible for binding of the bacterium to intestinal mucus. *Infect. Immun.* **60**: 3072-3078.
- Esaguy, N. and Aguas, A.P.** 1997. Subcellular localization of the 65-kDa heat shock protein in mycobacteria by immunoblotting and immunogold ultracytochemistry. *J. Submicrosc. Cytol. Pathol.* **29**: 85-90.
- Espinosa-Urgel, M., Salido, A. and Ramos, J.L.** 2000. Genetic analysis of functions involved in adhesion of *Pseudomonas putida* to seeds. *J. Bacteriol.* **182**: 2363-2369.
- Farinha, M.A., Conway, B.D., Ellert, L.M.G., Irvin, N.W., Sherburne, R. and Paranchych, W.** 1994. Alteration of the pilin adhesin of *Pseudomonas aeruginosa* PAO results in normal pilus biogenesis but a loss of adherence to human pneumocyte and decreased virulence in mice. *Infect. Immun.* **62**: 4118-4123.
- Fernandez, L.A. and Berenguer, J.** 2000. Secretion and assembly of regular surface structures in Gram-negative bacteria. *FEMS Microbiol. Rev.* **24**: 21-44.
- Filloux, A., Michel, G. and Bally, M.** 1998. GSP-dependent protein secretion in gram-negative bacteria: The Xcp system of *Pseudomonas aeruginosa*. *FEMS Microbiol. Rev.* **22**: 177-198.
- Fine, D.H., Furgang, D., Kaplan, J., Charlesworth, J. and Figurski, D.H.** 1999a. Tenacious adhesion of *Actinobacillus actinomycetemcomitans* strain CU1000 to salivary-coated hydroxyapatite. *Arch. Oral Biol.* **44**: 1063-1076.
- Fine, D.H., Furgang, D., Schreiner, H.C., Goncharoff, P., Charlesworth, J. and Ghazwan, G.** 1999b. Phneotypic variation in *Actinobacillus actinomycetemcomitans* during laboratory growth: Implications for virulence. *Microbiol.* **145**: 1335-1347.
- Fives-Taylor, P.M., Meyer, D.H., Mintz, K.P. and Brissette, C.** 2000. Virulence factors of *Actinobacillus actinomycetemcomitans*. *Periodontol.* **20**: 136-167.
- Flynn, G.C., Chappell, T.G. and Rothman, J.E.** 1989. Peptide binding and release by proteins implicated as catalysts of protein assembly. *Science* **245**: 385-390.
- Folkhard, W., Marvin, D.A., Watts, T.H. and Parenchych, W.** 1981. Structure of polar pili from *Pseudomonas aeruginosa* strain K and O. *J. Mol. Biol.* **149**: 79-93.
- Frisk, A., Ison, C.A. and Lagergard, T.** 1998. GroEL heat shock protein of *Haemophilus ducreyi*: Association with cell surface and capacity to bind to eukaryotic cells. *Infect. Immun.* **66**: 1252-1257.
- Gay, P., Le Coq, D., Steinmetz, M., Berkelman, T. and Kado, C.I.** 1985. Positive selection procedure for entrapment of insertion sequence elements in gram-negative bacteria. *J. Bacteriol.* **164**: 918-921.
- Genevaux, P., Bauda, P., DuBo, M.S. and Oudega, B.** 1999. Identification of Tn10 insertions in the *rfaG*; *rfaP* and *galU* genes involved in lipopolysaccharide core biosynthesis that affects *Escherichia coli* adhesion. *Arch. Microbiol.* **172**: 1-8.

Genevaux, P., Muller, S. and Bauda, P. 1996. A rapid screening procedure to identify mini-Tn10 insertion mutants of *Escherichia coli* K-12 with altered adhesion properties. *FEMS Microbiol. Lett.* **142**: 27-30.

Genin, S. and Boucher, C.A. 1994. A superfamily of proteins involved in different secretion pathways in gram-negative bacteria: Modular structure and specificity of the N-terminal domain. *Mol. Gen. Genet.* **243**: 112-118.

Gerhardt, P.H., Murray, R.G.E., Wood, W.A. and Krieg, N.G. 1994. Methods for General and Molecular Bacteriology. ASM Press, Washington D.C., USA.

Girón, J.A., Ho, A.S. and Schoolnik, G.K. 1991. An inducible bundle-forming pilus of enteropathogenic *Escherichia coli*. *Science* **254**: 710-713.

Gong, M. and Makowski, L. 1992. Helical structure of P pili from *Escherichia coli*. *J. Mol. Biol.* **228**: 735-742.

Goulhen, F., Hafezi, A., Uitto, V-J., Hinode, D., Nakamura, R., Grenier, D. and Mayrand, D. 1998. Subcellular localization and cytotoxic activity of the GroEL-like protein isolated from *Actinobacillus actinomycetemcomitans*. *Infect. Immun.* **66**: 5307-5313.

Govan, J.R. and Deretic, V. 1996. Microbial pathogenesis in cystic fibrosis: Mucoid *Pseudomonas aeruginosa* and *Burkholderia cepacia*. *Microbiol. Rev.* **60**: 539-574.

Graber, K.R., Smoot, L.M. and Actis, L.A. 1998. Expression of iron binding proteins and hemin binding activity in the dental pathogen *Actinobacillus actinomycetemcomitans*. *FEMS Microbiol. Lett.* **163**: 135-142.

Grahn, A.M., Haase, J., Bamford, D.H. and Lanka, E. 2000. Components of the RP4 conjugative transfer apparatus form an envelope structure bridging inner and outer membranes of donor cells: Implications for related macromolecule transport systems. *J. Bacteriol.* **182**: 1564-1574.

Greener, A., Lehman, S.M. and Helinski, D.R. 1992. Promoters of the broad-host-range plasmid RK2: Analysis of transcription (initiation) in five species of Gram-negative bacteria. *Genetics* **130**: 27-36.

Guilvout, I., Hardie, K.R., Sauvonnet, N. and Pugsley, A.P. 1999. Genetic dissection of the outer membrane secretin PulD: Are there domains for multimerization and secretion specificity? *J. Bacteriol.* **181**: 7212-7220.

Haase, E.M., Zmuda, J.L. and Scannapieco, F.A. 1999. Identification and molecular analysis of rough-colony-specific outer membrane proteins of *Actinobacillus actinomycetemcomitans*. *Infect. Immun.* **67**: 2901-2908.

Hahn, H.P. 1997. The type-4 pilus is the major virulence-associated adhesin of *Pseudomonas aeruginosa* - a review. *Gene* **192**: 99-108.

Hammar, M., Arnqvist, A., Bian, Z., Olsen, A. and Normark, S. 1995. Expression of two *csg* operons is required for production of fibronectin- and congo red-binding curli polymers in *Escherichia coli* K-12. *Mol. Microbiol.* **18**: 661-670.

Hammar, M., Bian, Z. and Normark, S. 1996. Nucleator-dependent intercellular assembly of adhesive curli organelles in *Escherichia coli*. *Proc. Natl. Acad. Sci. USA* **93**: 6562-6566.

- Harley, C.B. and Reynolds, R.P.** 1987. Analysis of *E. coli* promoter sequences. *Nucl. Acids Res.* **15**: 2343-2361.
- Hayashi, S. and Wu, H.C.** 1990. Lipoproteins in bacteria. *J. Bioenerg. Biomembr.* **22**: 451-471.
- Heilmann, C., Gerke, C., Perdreau-Remington, F. and Gotz, F.** 1996. Characterization of Tn917 insertion mutants of *Staphylococcus epidermidis* affected in biofilm formation. *Infect. Immun.* **64**: 277-282.
- Hensel, M. and Holden, D.W.** 1996. Molecular genetic approaches for the study of virulence in both pathogenic bacteria and fungi. *Microbiol.* **142**: 1049-1058.
- Herrington, D.A., Hall, R.H., Losonsky, G., Mekalanos, J.J., Taylor, R.K. and Levine, M.M.** 1988. Toxin, toxin-coregulated pilus, and the *tcpR* regulon are essential for *Vibrio cholerae* pathogenesis in humans. *J. Exp. Med.* **168**: 1487-1492.
- Heydorn, A., Ersball, B., Kato, J., Hentzel, M., Parsek, M.R., Tolker-Nielsen, T., Givskov, M. and Molin, S.** 2002. Statistical analysis of *Pseudomonas aeruginosa* biofilm development: Impact of mutations in genes involved in twitching motility, cell-to-cell signaling, and stationary phase sigma factor expression. *Appl. Environ. Microbiol.* **68**: 2008-2017.
- Hirose, I., Sano, K., Shioda, I., Kumano, M. and Nakamura, Y.K.** 2000. Proteome analysis of *Bacillus subtilis* extracellular proteins: A 2D study. *Microbiol.* **146**: 65-75.
- Hoang, T.T., Kutchma, A.J., Becher, A. and Schweizer, H.P.** 2000. Integration-proficient plasmid for *Pseudomonas aeruginosa*: Site-specific integration and use for engineering of reporter and expression strains. *Plasmid* **43**: 59-72.
- Hobbs, M. and Mattick, J.S.** 1993. Common components in the assembly of type 4 fimbriae, DNA transfer systems, filamentous phage and protein-secretion apparatus: A general system for the formation of surface-associated protein complexes. *Mol. Microbiol.* **10**: 233-243.
- Hofmann, K. and Stoffel, W.** 1993. Tmbase - a database of membrane-spanning protein segments. *Biol. Chem.* **374**: 166-172.
- Holmgren, A. and Branden, C.** 1989. Crystal structure of chaperone protein PapD reveals an immunoglobulin fold. *Nature* **342**: 248-251.
- Holt, S.C., Tanner, A.C. and Socransky, S.S.** 1980. Morphology and ultrastructure of oral strains of *Actinobacillus actinomycetemcomitans* and *Haemophilus aphrophilus*. *Infect. Immun.* **30**: 588-600.
- Hull, R.A., Gill, R.E., Hsu, P., Minshaw, B.H. and Falkow, S.** 1981. Construction and expression of recombinant plasmids encoding type 1 and D-mannose-resistant pili from a urinary tract infection *Escherichia coli* isolate. *Infect. Immun.* **33**: 933-938.
- Hultgren, S.J., Jones, C.H. and Normark, S.** 1996. Bacterial adhesins and their assembly. In: *Escherichia coli and Salmonella: Cellular and Molecular Biology*, Vol. 2, pp. 2730-2757. Neidhardt, F.C. (ed.). ASM Press, Washington, D.C., USA.
- Hultgren, S.J., Normark, S. and Abraham, S.N.** 1991. Chaperone-assisted assembly and molecular architecture of adhesive pili. *Annu. Rev. Microbiol.* **45**: 383-415.
- Hung, D.L. and Hultgren, S.J.** 1998. Pilus biogenesis via the chaperone/usher pathway: An integration of structure and function. *J. Struct. Biol.* **124**: 201-220.

- Inoue, T., Tanimoto, I., Ohta, H., Kato, K., Murayama, Y. and Fukui, K.** 1998. Molecular characterization of low-molecular-weight component protein, Flp, in *Actinobacillus actinomycetemcomitans* fimbriae. *Microbiol. Immunol.* **42:** 253-258.
- Inouye, T., Ohta, H., Kogekuchi, S., Fukui, K. and Kato, K.** 1990. Colonial variation and fimbriation of *Actinobacillus actinomycetemcomitans*. *FEMS Microbiol. Lett.* **57:** 13-17.
- Iredell, J.R. and Manning, P.A.** 1997. Translocation failure in type 4 pilin operon: *rfb* and *tcpT* mutants in *Vibrio cholerae*. *Gene* **192:** 71-77.
- Jacob-Dubuisson, F., Heuser, J., Dodson, K., Normark, S. and Hultgren, S.J.** 1993. Initiation of assembly and association of the structural elements of a bacterial pilus depend on two specialized tip proteins. *EMBO J.* **12:** 837-847.
- Jacob-Dubuisson, F., Pinkner, J., Xu, Z., Striker, R., Padmanhaban, A. and Hultgren, S.J.** 1994. PapD chaperone function in pilus biogenesis depends on oxidant and chaperone-like activities of DsbA. *Proc. Natl. Acad. Sci. USA* **91:** 11552-11556.
- Jansen, K.** (ed). 1995. Current Protocols in Molecular Biology. John Wiley & Sons Inc., USA.
- Jeon, Y.H., Negishi, T., Shirakawa, M., Yamazaki, T., Fujita, N., Ishihama, A. and Kyoyoku, Y.** 1995. Solution structure of the activator contact domain of the RNA polymerase alpha subunit. *Science* **270:** 1495-1497.
- Jones, C.H., Danese, P.N., Pinkner, J.S., Silhavy, T.J. and Hultgren, S.J.** 1997. The chaperone-assistant membrane release and folding pathway is sensed by two signal transduction systems. *EMBO J.* **16:** 6394-6406.
- Jones, C.H., Pinkner, J.S., Nicholes, A.V., Slonim, L.N., Abraham, S.N. and Hultgren, S.J.** 1993. FimC is a periplasmic PapD-like chaperone that directs assembly of type 1 pili in bacteria. *Proc. Natl. Acad. Sci. USA* **90:** 8397-8401.
- Jones, C.H., Pinkner, J.S., Roth, R., Heuser, J., Nicholoes, A.V., Abraham, S.N. and Hultgren, S.J.** 1995. FimH adhesin of type 1 pili is assembled into a fibrillar tip structure in the *Enterobacteriaceae*. *Proc. Natl. Acad. Sci. USA* **92:** 2081-2085.
- Kachlany, S.C., Planet, P.J., Bhattacharjee, M.K., Kollia, E., DeSalle, R., Fine, D.H. and Figurski, D.H.** 2000. Nonspecific adherence of *Actinobacillus actinomycetemcomitans* requires genes widespread in *Bacteria* and *Archaea*. *J. Bacteriol.* **182:** 6169-6176.
- Kachlany, S.C., Planet, P.J., DeSalle, R., Fine, D.H., Figurski, D.H. and Kaplan, J.** 2001. *fip-1*, the first representative of a new pilin gene subfamily, is required for non-specific adherence of *Actinobacillus actinomycetemcomitans*. *Mol. Microbiol.* **40:** 542-554.
- Kadurugamuwa, J.L. and Beveridge, T.J.** 1995. Virulence factors are released from *Pseudomonas aeruginosa* in association with membrane vesicles during normal growth and exposure to gentamicin: A novel mechanism of enzyme secretion. *J. Bacteriol.* **177:** 3998-4008.
- Kadurugamuwa, J.L., Clarke, A.J. and Beveridge, T.J.** 1993. Surface action of gentamicin on *Pseudomonas aeruginosa*. *J. Bacteriol.* **175:** 5798-5805.
- Kang, P.J., Hauser, A.R., Apodaca, G., Fleizig, S.M., Wiener-Kronish, J., Mostov, K. and Engel, J.N.** 1997. Identification of *Pseudomonas aeruginosa* genes required for epithelial cell injury. *Mol. Microbiol.* **24:** 1249-1262.

- Kaufman, M.R., Seyer, J.M. and Taylor, R.T.** 1991. Processing of Tcp pilin by TcpJ typifies a common step intrinsic to a newly recognized pathway for extracellular protein secretion by Gram-negative bacteria. *Genes Dev.* **5:** 1834-1846.
- Kaufman, M.R., Shaw, C.E., Jones, I.D. and Taylor, R.K.** 1993. Biogenesis and regulation of the *Vibrio cholera* toxin-coregulated pilus: Analogies to other virulence factor secretory systems. *Gene* **126:** 43-49.
- Klemm, P. and Christiansen, G.** 1990. The *fimD* gene required for cell surface localization of *Escherichia coli* type 1 fimbriae. *Mol. Gen. Genet.* **220:** 334-338.
- Knox, J.R. and Moews, P.C.** 1991. Beta-lactamase of *Bacillus licheniformis* 749/c. Refinement at 2 Å resolution and analysis of hydration. *J. Mol. Biol.* **220:** 435-455.
- Korber, D., Lawrence, J.R. and Caldwell, D.E.** 1994. Effect of motility on surface colonisation and reproductive success of *Pseudomonas fluorescens* in dual-dilution continuous culture and batch culture systems. *Appl. Environ. Microbiol.* **60:** 1663-1669.
- Korber, D.R., Lawrence, J.R., Sutton, B. and Caldwell, D.E.** 1989. Effects of laminar flow velocity on the kinetics of surface colonization by mot⁺ and mot⁻ *Pseudomonas fluorescens*. *Microb. Ecol.* **18:** 1-19.
- Krause, S., Pansegrau, W., Lurz, R., de la Cruz, F. and Lanka, E.** 2000. Enzymology of type IV macromolecule secretion systems: The conjugative transfer regions of plasmids RP4 and R388 and the *cag* pathogenicity island of *Helicobacter pylori* encode structurally and functionally related nucleoside triphosphate hydrolases. *J. Bacteriol.* **182:** 2761-2770.
- Krogfeldt, K.A., Bergmans, H. and Klemm, P.** 1990. Direct evidence that the FimH protein is the mannose-specific adhesin for *Escherichia coli* type 1 fimbriae. *Infect. Immun.* **58:** 1995-1999.
- Kuehn, M.J., Heuser, J., Normark, S. and Hultgren, S.J.** 1992. P pili in uropathogenic *E. coli* are composite fibers with distinct fibrillar adhesive tips. *Nature* **356:** 252-255.
- Kuehn, M.J., Jacob-Dubuisson, F., Dodson, K., Slanim, L., Striker, R. and Hultgren, S.J.** 1994. Genetic, biochemical and structural studies of biogenesis of adhesive pili in bacteria. *Meth. Enzymol.* **236:** 282-303.
- Kuehn, M.J., Normark, S. and Hultgren, S.J.** 1991. Immunoglobulin-like PapD chaperone caps and uncaps interactive surfaces of nascently translocated pilus subunits. *Proc. Natl. Acad. Sci. USA* **88:** 10586-10590.
- Kuehn, M.J., Ogg, D.J., Kihlberg, J., Slanim, L.N., Flemmer, K., Bergfors, T. and Hultgren S.J.** 1993. Structural basis of pilus subunit recognition by the PapD chaperone. *Science* **262:** 1234-1241.
- Kurchma, S.L. and O'Toole, G.A.** 2000. Surface-induced and biofilm-induced changes in gene expression. *Curr. Opin. Biotechnol.* **11:** 429-433.
- Laemmli, U.K.** 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* **227:** 680-685.
- LaPointe, C.F. and Taylor, R.K.** 2000. The type 4 prepilin peptidases comprise a novel family of aspartic acid proteases. *J. Biol. Chem.* **275:** 1502-1510.
- La Tourette Prosser, B., Taylor, D., Dix, B.A. and Cleeland, R.** 1987. Method of evaluating effects of antibiotics on bacterial biofilm. *Antimicrob. Agents Chemother.* **31:** 1502-1506.

- Lawrence, J.R., Korber, D.R., Hoyle, B.D., Costerton, J.W. and Caldwell, D.E.** 1991. Optical sectioning of microbial biofilms. *J. Bacteriol.* **173**: 6558-6567.
- Lazdunski, A., Guzzo, J., Filloux, A., Bally, M. and Murgier, M.** 1990. Secretion of extracellular proteins by *Pseudomonas aeruginosa*. *Biochem.* **72**: 147-156.
- Lee, K.K., Sheth, H.B., Wong, W.Y., Sherburne, R., Paranchych, W., Hodges, R.S., Lingwood, C.A., Krivan, H. and Irvin, R.T.** 1994. The binding of *Pseudomonas aeruginosa* pili to glycosphingolipids is a tip-associated event involving the C-terminal region of the structural pilin subunit. *Mol. Microbiol.* **11**: 705-713.
- Li, Z., Clarke, A.J. and Beveridge, T.J.** 1996. A major autolysin of *Pseudomonas aeruginosa*: Subcellular distribution, potential role in cell growth and division and secretion in surface membrane vesicles. *J. Bacteriol.* **178**: 2479-2488.
- Linderoth, N.A., Simon, M.N. and Russel, M.** 1997. The filamentous phage pIV multimer visualized by scanning transmission electron microscopy. *Science* **278**: 1635-1638.
- Liu, P.V.** 1974. Extracellular toxins of *Pseudomonas aeruginosa*. *J. Infect. Dis.* **130**: 94-99.
- Loferer, H., Hammar, M. and Normark, S.** 1997. Availability of the fibre subunit CsgA and the nucleator protein CsgB during assembly of fibronectin-binding curli is limited by the intracellular concentration of the novel lipoprotein CsgG. *Mol. Microbiol.* **26**: 11-23.
- Loo, C.Y., Corliss, D.A. and Ganeshkumar, N.** 2000. *Streptococcus gordonii* biofilm formation: Identification of genes that code for biofilm phenotypes. *J. Bacteriol.* **182**: 1374-1382.
- Lory, S.** 1998. Secretion of proteins and assembly of bacterial surface organelles: Shared pathways of extracellular protein targeting. *Curr. Opin. Microbiol.* **1**: 27-35.
- Luckow, V.A., Lee, S.C., Barry, G.F. and Olins, P.O.** 1993. Efficient generation of infectious recombinant baculoviruses by site-specific transposon-mediated insertion of foreign genes into a baculovirus genome propagated in *Escherichia coli*. *J. Virol.* **67**: 4566-4579.
- MacDonald, R. and Brözel, V.S.** 2000. Community analysis of bacterial biofilms in a simulated recirculating cooling-water system by fluorescent *in situ* hybridization with rRNA-targeted oligonucleotide probes. *Water Res.* **34**: 2439-2446.
- Maguire, B.A. and Zimmermann, R.A.** 2001. The ribosome in focus. *Cell* **104**: 813-816.
- Maloy, S.R. and Nunn, W.D.** 1981. Role of gene *fadR* in *Escherichia coli* acetate metabolism. *J. Bacteriol.* **148**: 83-90.
- Marklund, B.L., Tennent, J.M., Garcia, E., Hamers, A., Baga, M., Lindberg, F., Gaastra, W. and Normark, S.** 1992. Horizontal gene transfer of the *Escherichia coli* *pap* and *prs* pili operons as a mechanism for the development of tissue-specific adhesive properties. *Mol. Microbiol.* **6**: 2225-2242.
- Marshall, K.C.** 1985. Mechanisms of bacterial adhesion at solid-water interfaces. In: *Bacterial Adhesion: Mechanisms and Physiological Significance*, pp. 133-161. Savage, D.C. and Fletcher, M. (eds). Plenum Press, New York, USA.
- Marshall, K.C.** 1992. Biofilms: An overview of bacterial adhesion, activity and control at surfaces. *ASM News* **58**: 202-207.

- Marshall, K.C., Stout, R. and Mitchell, R.** 1971. Mechanisms of the initial events in the sorption of marine bacteria to solid surfaces. *J. Gen. Microbiol.* **68**: 337-348.
- Martin, P.R., Hobbs, M., Free, P.D., Jeske, Y. and Mattick, J.S.** 1993. Characterization of *pilQ*, a new gene required for the biogenesis of type 4 fimbriae in *Pseudomonas aeruginosa*. *Mol. Microbiol.* **9**: 857-868.
- Martin, P.R., Watson, A., McCaul, T. and Mattick, J.S.** 1995. Characterisation of a five-gene cluster required for the biogenesis of type 4 fimbriae in *Pseudomonas aeruginosa*. *Mol. Microbiol.* **16**: 497-508.
- Martínez, A., Ostrovsky, P. and Nunn, D.N.** 1998. Identification of an additional member of the secretin superfamily of proteins in *Pseudomonas aeruginosa* that is able to function in type II protein secretion. *Mol. Microbiol.* **28**: 1235-1246.
- Mattick, J.S., Whitchurch, C.B. and Alm, R.A.** 1996. The molecular genetics of type IV fimbriae in *Pseudomonas aeruginosa* - a review. *Gene* **179**: 147-155.
- Maurer, L. and Orndorff, P.E.** 1985. A new locus *pile* required for the binding of type 1-piliated *Escherichia coli* to erythrocytes. *FEMS Microbiol. Lett.* **30**: 59-66.
- May, T.B., Shinabarger, D., Maharaj, R., Kato, J., Chu, L., DeVault, J.D., Roychoudhury, S., Zielinski, N.A., Berry, A., Rothmel, R.K., Misra, T.K. and Chakrabarty, A.M.** 1991. Alginate synthesis by *Pseudomonas aeruginosa*: A key pathogenic factor in chronic pulmonary infections of cystic fibrosis patients. *Clin. Microbiol. Rev.* **4**: 191-206.
- Mayrand, D. and Holt, S.C.** 1988. Biology of a saccharolytic black-pigmented *Bacteroides* species. *Microbiol. Rev.* **52**: 134-152.
- McLean, J.J.C., Whitely, M., Strickler, D.J. and Fuqua, W.C.** 1997. Evidence of autoinducer activity in naturally occurring biofilms. *FEMS Microbiol. Lett.* **154**: 259-263.
- Moller, W. and Amons, R.** 1985. Phosphate-binding sequences in nucleotide-binding proteins. *FEBS Lett.* **186**: 1-7.
- Muller, E., Hubner, J., Gutierrez, N., Takeda, S., Goldmann, D.A. and Pier, G.B.** 1993. Isolation and characterization of transposon mutants of *Staphylococcus epidermidis* deficient in capsular polysaccharide/adhesin and slime. *Infect. Immun.* **61**: 551-558.
- Mulvey, M.A., Lopez-Boado, Y.S., Wilson, C.L., Roth, R., Parks, W.C., Heuser, J. and Hultgren, S.J.** 1998. Induction and evasion of host defences by type 1-piliated uropathogenic *Escherichia coli*. *Science* **282**: 1494-1497.
- Nakai, K. and Kanehisa, M.** 1991. Expert system for predicting protein localization sites in gram-négative bacteria. *Prot.* **11**: 95-110.
- Nassif, X., Beretti, J.L., Lowy, J., Stenberg, P., O'Gaora, P., Pfeifer, J., Normark, S. and So, M.** 1994. Roles of pilin and PilC in adhesion of *Neisseria meningitidis* to human epithelial and endothelial cells. *Proc. Natl. Acad. Sci. USA* **91**: 3769-3773.
- Nickel, J.C., Rusesa, I., Wright, J.B. and Costerton, J.W.** 1985. Tobramycin resistance of *Pseudomonas aeruginosa* growing as a biofilm on urinary catheter material. *Antimicrob. Agents Chemother.* **27**: 619-624.

- Nielsen, H., Engelbrecht, J., Brunnak, S. and Van Heijne, G.** 1997. Identification of prokaryotic and eukaryotic signal peptides and prediction of their cleavage sites. *Prot. Eng.* **10**: 1-6.
- Nika, J.R., Latimer, J.L., Ward, C.K., Blick, R.J., Wagner, N.J., Cope, L.D., Mahairas, G.G., Munson, R.S. and Hansen, E.J.** 2002. *Haemophilus ducreyi* requires the *fhp* gene cluster for microcolony formation *in vitro*. *Infect. Immun.* **70**: 2965-2975.
- Nivens, D.E., Ohman, D.E., Williams, J. and Franklin, M.J.** 2001. Role of alginate and its O-acetylation in formation of *Pseudomonas aeruginosa* microcolonies and biofilms. *J. Bacteriol.* **183**: 1047-1057.
- Norgen, M., Baga, M., Tennent, J.M. and Normark, S.** 1987. Nucleotide sequence, regulation and functional analysis of the *papC* gene required for cell surface localization of Pap pili of uropathogenic *Escherichia coli*. *Mol. Microbiol.* **1**: 169-178.
- Nouwen, N., Ranson, N., Saibil, H., Wolpensinger, B., Engel, A., Ghazi, A. and Pugsley, A.P.** 1999. Secretin PulD: Association with pilot PulS, structure and ion-conducting channel formation. *Proc. Natl. Acad. Sci. USA* **96**: 8173-8177.
- Nouwens, A.S., Willcox, M.D.P., Walsh, B.J. and Cordwell, S.J.** 2002. Proteomic comparison of membrane and extracellular proteins from invasive (PAO1) and cytotoxic (6206) strains of *Pseudomonas aeruginosa*. *Proteomics* **2**: 1325-1346.
- Nunn, D.** 1999. Bacterial Type II protein export and pilus biogenesis: More than just homologies? *Trends. Cell. Biol.* **9**: 402-408.
- Nunn, D., Bergman, S. and Lory, S.** 1990. Products of three accessory genes *pilB*, *pilC* and *pilD*, are required for biogenesis of *Pseudomonas aeruginosa* pili. *J. Bacteriol.* **172**: 2911-2919.
- Nunn, D. and Lory, S.** 1991. Product of the *Pseudomonas aeruginosa* gene *pilD* is a prepilin leader peptidase. *Proc. Natl. Acad. Sci. USA* **89**: 47-51.
- Nunn, D. and Lory, S.** 1992. Components of the protein excretion apparatus of *Pseudomonas aeruginosa* are processed by the type IV prepilin peptidase. *Proc. Natl. Acad. Sci. USA* **89**: 47-51.
- O'Farrell, P.H.** 1975. High resolution two-dimensional electrophoresis of proteins. *J. Biol. Chem.* **250**: 4007-4021.
- Olsen, A., Arnqvist, A., Hammar, M. and Normark, S.** 1993. Environmental regulation of curli production in *Escherichia coli*. *Infect. Agents Dis.* **2**: 272-274.
- Olsen, R.H., DeBusscher, G. and McCombie, W.R.** 1982. Development of broad range and gene banks: Self-cloning of the *Pseudomonas aeruginosa* PAO chromosome. *J. Bacteriol.* **150**: 60-69.
- Olsen, A., Jonsson, A. and Normark, S.** 1989. Fibronectin binding mediated by a novel class of surface organelles on *Escherichia coli*. *Nature* **338**: 652-655.
- Olsen, R.H. and Shipley, P.** 1973. Host range and properties of the *Pseudomonas aeruginosa* R factor R1822. *J. Bacteriol.* **113**: 772-780.
- Oosthuizen, M.C., Steyn, B., Theron, J., Cosette, P., Lindsay, D., Van Holty, A. and Brözel, V.S.** 2002. Proteomic analysis reveals differential protein expression by *Bacillus cereus* during biofilm development. *Appl. Environ. Microbiol.* **68**: 2770-2780.

- Orndorff, P.E. and Bloch, C.A.** 1990. The role of type I pili in the pathogenesis of *Escherichia coli* infections: A short review and some new ideas. *Microb. Pathog.* **9**: 75-79.
- O'Shea, E.K., Rutkowski, R. and Kim, P.S.** 1989. Evidence that the leucine zipper is a coiled coil. *Science* **243**: 538-542.
- O'Toole, G.A., Kaplan, H.B. and Kolter, R.** 2000. Biofilm formation as microbial development. *Annu. Rev. Microbiol.* **54**: 49-79.
- O'Toole, G.A. and Kolter, R.** 1998a. Flagellar and twitching motility are necessary for *Pseudomonas aeruginosa* biofilm development. *Mol. Microbiol.* **30**: 295-304.
- O'Toole, G.A. and Kolter, R.** 1998b. Initiation of biofilm formation in *Pseudomonas fluorescens* WCS365 proceeds via multiple, convergent signalling pathways: A genetic analysis. *Mol. Microbiol.* **28**: 449-461.
- Paetzel, M., Dalbey, R.E. and Strynadka, C.J.** 2000. The structure and mechanism of bacterial type I signal peptidases: A novel antibiotic target. *Pharmacol. Therapeutics* **87**: 27-49.
- 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.
- Parsons, L.M., Limberger, R.J. and Shayegani, M.** 1997. Alterations in levels of DnaK and GroEL result in diminished survival and adherence of stressed *Haemophilus ducreyi*. *Infect. Immun.* **65**: 2413-2419.
- Pearson, W.R., Wood, T., Zhang, Z. and Miller, W.** 1997. Comparison of DNA sequences with protein sequences. *Genomics* **46**: 24-36.
- Pederson, S., Bloch, P.J., Reeh, S. and Neidhardt, F.C.** 1978. Patterns of protein synthesis in *Escherichia coli*: A catalogue of the amount of 140 individual proteins at different growth rates. *Cell* **141**: 179-190.
- Pelicic, V., Reyrat, J.M. and Gicquel, B.** 1996. Generation of unmarked directed mutations in mycobacteria, using sucrose counter-selectable suicide vectors. *Mol. Microbiol.* **20**: 919-925.
- Pepe, J.C. and Lory, S.** 1998. Amino acid substitutions in PilD, a bifunctional enzyme of *Pseudomonas aeruginosa*: Effect on leader peptidase and N-methyltransferase activities *in vitro* and *in vivo*. *J. Biol. Chem.* **273**: 19120-19129.
- Phadnis, S.H., Parlow, M.H., Levy, M., Caulkins, C.M., Connors, J.B. and Dunn, B.E.** 1996. Surface localization of *Helicobacter pylori* urease and a heat shock protein requires bacterial autolysis. *Infect. Immun.* **64**: 905-912.
- Piette, J.P. and Odziak, E.S.** 1992. A model study of factors involved in adhesion of *Pseudomonas fluorescens* to meat. *Appl. Environ. Microbiol.* **58**: 2783-2791.
- Planet, P.J., Kachlany, S.C., DeSalle, R. and Figurski, D.H.** 2001. Phylogeny of genes for secretion NTPases: Identification of the widespread *tadA* subfamily and development of a diagnostic key for gene classification. *Proc. Natl. Acad. Sci. USA* **98**: 2503-2508.
- Pogliano, J., Lynch, A.S., Belin, D., Lin, E.C.C. and Beckwith, J.** 1997. Regulation of *Escherichia coli* cell envelope proteins involved in protein folding and degradation by the Cpx two-component system. *Genes Dev.* **11**: 1169-1182.

- Possot, O.** and **Pugsley, A.P.** 1994. Molecular characterization of PulE, a protein required for pullulanase secretion. *Mol. Microbiol.* **12**: 287-299.
- Possot, O.** and **Pugsley, A.P.** 1997. The conserved tetracysteine motif in the general secretory pathway component PulE is required for efficient pullulanase secretion. *Gene* **192**: 45-50.
- Pratt, L.A.** and **Kolter, R.** 1998. Genetic analysis of *Escherichia coli* biofilm formation: Roles of flagella, motility, chemotaxis and type 1 pili. *Mol. Microbiol.* **30**: 285-293.
- Prigent-Combaret, C., Vidal, O., Dorel, C.** and **Lejeune, P.** 1999. Abiotic surface sensing and biofilm-dependent regulation of gene expression in *Escherichia coli*. *J. Bacteriol.* **181**: 5993-6002.
- Provence, D.L.** and **Curtiss, R.** 1992. Role of *crl* in avian pathogenic *Escherichia coli*: A knockout mutation of *crl* does not affect hemagglutination activity, fibronectin binding or curli production. *Infect. Immun.* **60**: 4460-4467.
- Pugsley, A.P.** 1993. The complete general secretory pathway in Gram-negative bacteria. *Microbiol. Rev.* **57**: 50-108.
- Pugsley, A.P.** 1996. Multimers of the precursor of a type IV pilin-like component of the general secretory pathway are unrelated to pili. *Mol. Microbiol.* **20**: 1235-1245.
- Quirynen, M., Mongardin, C., de Soete, M., Pauwels, M., Coucke, W., van Eldere, J.** and **van Steenberg, D.** 2000. The role of chlorhexidine in the one-stage full mouth disinfection treatment of patients with advanced adult periodontitis: Long-term disinfection and microbiological observations. *J. Clin. Periodontol.* **27**: 578-589.
- Raina, S.** and **Missiakas, D.** 1997. Making and breaking disulfide bonds. *Annu. Rev. Microbiol.* **51**: 179-202.
- Rashkova, S., Spudich, G.M.** and **Christie, P.J.** 1997. Characterization of membrane and protein interaction determinants of the *Agrobacterium tumefaciens* VirB11 ATPase. *J. Bacteriol.* **179**: 583-591.
- Rashkova, S., Zhou, X.R., Chen, J.** and **Christie, P.J.** 2000. Self-assembly of the *Agrobacterium tumefaciens* VirB11 traffic ATPase. *J. Bacteriol.* **182**: 4137-4145.
- Rehmat, S.** and **Shapiro, J.A.** 1983. Insertion and replication of the *Pseudomonas aeruginosa* mutator phage D3112. *Mol. Gen. Genet.* **192**: 416-423.
- Rice, A.R., Hamilton, M.A.** and **Camper, A.K.V.** 2000. Apparent surface associated lag time in growth of primary biofilm cells. *Microb. Ecol.* **41**: 8-15.
- Rivas, S., Bolland, S., Cabezon, E., Goni, F.M.** and **de la Cruz, F.** 1997. TrwD, a protein encoded by the IncW plasmid R388, displays an ATP hydrolase activity essential for bacterial conjugation. *J. Biol. Chem.* **272**: 25583-25590.
- Roberts, J.A., Marklund, B.I., Ilver, D., Haslam, D., Kaack, M.B., Baskin, G., Louis, M., Mollby, R., Winberg, J.** and **Normark, S.** 1994. The Gal $\alpha(1-4)$ Gal-specific tip adhesin of *Escherichia coli* P-fimbriae is needed for pyelonephritis to occur in the normal urinary tract. *Proc. Natl. Acad. Sci. USA* **91**: 11889-11893.
- Romling, U., Brian, Z., Hammar, M., Sierralta, W.D.** and **Normark, S.** 1998. Curli fibres are highly conserved between *Salmonella typhimurium* and *Escherichia coli* with respect to open structures and regulation. *J. Bacteriol.* **180**: 722-731.

- Roncero, C., Darzins, A. and Casadaban, M.J.** 1990. *Pseudomonas aeruginosa* transposable bacteriophages D3112 and B3 require pili and surface growth for adsorption. *J. Bacteriol.* **172**: 1899-1904.
- Rudel, T., Scheurepflug, I. and Meyer, T.F.** 1995. *Neisseria* PilC protein identified as type-4 pilus tip-located adhesin. *Nature* **373**: 357-359.
- Russel, M.** 1998. Macromolecular assembly and secretion across the bacterial cell envelope: Type II protein secretion systems. *J. Mol. Biol.* **279**: 485-499.
- Russel, M., Linderoth, N.A. and Sali, A.** 1997. Filamentous phage assembly: Variation on a protein export theme. *Gene* **192**: 23-32.
- Russel, P.W. and Orndorff, P.E.** 1992. Lesions in two *Escherichia coli* type 1 pilus genes affect pilus number and length without affecting receptor binding. *J. Bacteriol.* **174**: 5923-5935.
- Russell, M.A. and Darzins, A.** 1994. The *pilE* gene product of *Pseudomonas aeruginosa*, required for pilus biogenesis, shares amino acid sequence identity with the N-terminal of type 4 prepilin proteins. *Mol. Microbiol.* **13**: 973-985.
- Ryll, R.R., Rudel, T., Scheuerpflug, I., Barten, R. and Meyer, T.F.** 1997. PilC of *Neisseria meningitidis* is involved in class II pilus formation and restores pilus assembly, natural transformation competence and adherence to epithelial cells in PilC-deficient gonococci. *Mol. Microbiol.* **23**: 879-892.
- Saiman, L., Ishimoto, K., Lory, S. and Prince, A.** 1990. The effect of piliation and exoprotein expression on the adherence of *Pseudomonas aeruginosa* to respiratory epithelial monolayers. *J. Infect. Dis.* **161**: 541-548.
- Sambrook, J., Fritsch, E.F. and Maniates, T.** 1989. Molecular cloning: A Laboratory Manual. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, USA.
- Sauer, K. and Camper, A.K.** 2001. Characterisation of phenotypic changes in *Pseudomonas putida* in response to surface-associated growth. *J. Bacteriol.* **183**: 6579-6589.
- Sauer, K., Camper, A.K., Ehrlich, G.D., Costerton, J.W. and Davies, D.G.** 2002. *Pseudomonas aeruginosa* displays multiple phenotypes during development as a biofilm. *J. Bacteriol.* **184**: 1140-1154.
- Sauer, F.G., Futterer, K., Pinker, J.S., Dodson, K.W., Hultgren, S.J. and Waksman, G.** 1999. Structural basis of chaperone function and pilus biogenesis. *Science* **285**: 1058-1061.
- Sauer, F.G., Mulvey, M.A., Schilling, J.D., Martinez, J.J. and Hultgren, S.J.** 2000. Bacterial pili: Molecular mechanisms of pathogenesis. *Curr. Opin. Microbiol.* **10**: 548-556.
- Saulino, E.T., Thanassi, D.G., Pinker, J.S. and Hultgren, S.J.** 1998. Ramifications of kinetic partitioning on usher-mediated pilus biogenesis. *EMBO J.* **17**: 2177-2185.
- Seahill, S., Campbell, J.I.A., Ambler, R.P. and Gibson, T.** 1989. The phototrophic bacterium *Rhodopseudomonas capsulata* sp. 108 encodes an indigenous class A beta-lactamase. *Biochem. J.* **260**: 803-812.
- Scharfman, A., Kroczyński, H., Carnoy, C., Van Brussel, E., Lamblin, G., Ramphal, R. and Roussel, P.** 1996. Adhesion of *Pseudomonas aeruginosa* to respiratory mucins and expression of mucin-binding proteins are increased by limiting iron during growth. *Infect. Immun.* **64**: 5417-5420.

- Schilling, J.D., Mulvey, M.A. and Hultgren, S.J.** 2001. Structure and function of *Escherichia coli* type 1 pili: New insight into pathogenesis of urinary tract infections. *J. Inf. Dis.* **183**(Suppl 1): S36-40.
- Schmid, M.B. and von Freiesleben, U.** 1996. Nucleoid segregation. In: *Escherichia coli and Salmonella: Cellular and Molecular Biology*, Vol. 2, pp. 1662-1671. Neihardt, F.C. (ed.). ASM Press, Washington, D.C., USA.
- Schuster, M., Lostroh, C.P., Ogi, T. and Greenberg, E.P.** 2003. Identification, timing, and signal specificity of *Pseudomonas aeruginosa* quorum-controlled genes: A transcriptome analysis. *J. Bacteriol.* **185**: 2066-2079.
- Scorpio, A., Johnson, P., Laquerre, A. and Nelson, D.R.** 1994. Subcellular localization and chaperone activities of *Borrelia burgdorferi* Hsp60 and Hsp70. *J. Bacteriol.* **176**: 6449-6456.
- Semmler, A.B.T., Whitchurch, C.B. and Mattick, J.S.** 1999. A re-examination of twitching motility in *Pseudomonas aeruginosa*. *Microbiol.* **145**: 2863-2873.
- Seraste, M., Sibbald, P.R. and Wittinghofer, A.** 1990. The P-loop - A common motif in ATP- and GTP-binding proteins. *TIBS* **15**: 430-434.
- Skrekker, J.M. and Shapiro, L.** 2000. Identification and cell cycle control of a novel pilus system in *Caulobacter crescentus*. *EMBO J.* **13**: 3223-3234.
- Slots, J., Reynolds, H.S. and Genco, R.J.** 1980. *Actinobacillus actinomycetemcomitans* in human periodontal disease: A cross-sectional microbiological investigation. *Infect. Immun.* **29**: 1013-1020.
- Slots, J. and Ting, M.** 1999. *Actinobacillus actinomycetemcomitans* and *Porphyromonas gingivalis* in human periodontal disease: Occurrence and treatment. *Periodontol.* **20**: 82-121.
- Smith, J.J.** 2003. Towards the development of a biofilm-specific expression system: Effects of different promoters, gene dosage and growth phases on extracellular expression of *Pseudomonas aeruginosa* DSM1707 alkaline protease. M.Sc Thesis, Department of Microbiology and Plant Pathology, University of Pretoria, South Africa.
- Smyth, C.J., Marron, M.B., Twohig, J.M. and Smith, G.J.** 1996. Fimbrial adhesins: Similarities and variations in structure and biogenesis. *FEMS Immun. Medical Microbiol.* **16**: 127-139.
- Soto, G.E., Dodson, K.W., Ogg, D., Liu, C., Heuser, J., Knight, S., Kihlberg, J., Jones, C.H. and Hultgren, S.J.** 1998. Periplasmic chaperone recognition motif of subunits mediating quaternary interactions in the pilus. *EMBO J.* **17**: 6155-6167.
- Soto, G.E. and Hultgren, S.J.** 1999. Bacterial adhesins: Common themes and variation in architecture and assembly. *J. Bacteriol.* **181**: 1059-1071.
- Southern, E.M.** 1975. Detection of specific sequences among DNA fragments separated by gel electrophoresis. *J. Mol. Biol.* **98**: 503-517.
- Stephens, K.M., Roush, C. and Nester, E.** 1995. *Agrobacterium tumefaciens* VirB11 protein requires a consensus nucleotide-binding site for function in virulence. *J. Bacteriol.* **177**: 27-36.
- Steyn, B., Oosthuizen, M.C., MacDonald, R., Theron, J. and Brözel, V.S.** 2001. The use of glass wool as an attachment surface for studying phenotypic changes in *Pseudomonas aeruginosa* biofilms by two-dimensional gel electrophoresis. *Proteomics* **1**: 871-879.

Stone, K.D., Zhang, H.K., Carlson, L.K. and Donnenberg, M.S. 1996. A cluster of fourteen genes from enteropathogenic *Escherichia coli* is sufficient for the biogenesis of a type IV pilus. *Mol. Microbiol.* **20**: 325-337.

Stover, K.C., Pham, X.Q., Erwin, A.L., Mizoguchi, S.D., Warrener, P., Hickey, M.J., Brinkman, F.S.L., Hufnagle, W.O., Kowalik, D.J., Lagrou, M., Garber, R.L., Goltry, L., Tolentino, E., Westbroek-Wadman, S., Yuan, Y., Brody, L.L., Coulter, S.N., Folger, K.R., Kas, A., Larbig, K., Lim, R., Smith, K., Spencer, D., Wong, G.K.-S., Wu, Z., Paulsen, I., Reizer, J., Saier, M.H., Hancock, R.E.W., Lory, S. and Olson, M.V. 2000. Complete genome sequence of *Pseudomonas aeruginosa* PAO1: An opportunistic pathogen. *Nature* **406**: 959-964.

Strom, M.S., Bergman, P. and Lory, S. 1993. Identification of active-site cysteines in the conserved domain of PilD, the bifunctional type IV pilin leader peptidase/N-methyltransferase of *Pseudomonas aeruginosa*. *J. Biol. Chem.* **268**: 15788-15794.

Strom, M. and Lory, S. 1992. Kinetics and sequence specificity of processing of prepilin by PilD, the type IV leader peptidase of *Pseudomonas aeruginosa*. *J. Bacteriol.* **174**: 7345-7351.

Strom, M. and Lory, S. 1993. Structure-function and biogenesis of type IV pili. *Annu. Rev. Microbiol.* **47**: 565-596.

Strom, M.S., Nunn, D. and Lory, S. 1991. Multiple roles of the pilus biogenesis protein PilD: Involvement of PilD in excretion of enzymes from *Pseudomonas aeruginosa*. *J. Bacteriol.* **173**: 1175-1180.

Subramanian, A.R. 1983. Structure and functions of ribosomal protein S1. *Prog. Nucl. Acid Res. Biol.* **28**: 101-142.

Suh, S.J., Silo-Suh, L., Woods, D.E., Hassett, D.J., West, S.E. and Ohman, D.E. 1999. Effects of *rpoS* mutation on the stress response and expression of virulence factors in *Pseudomonas aeruginosa*. *J. Bacteriol.* **181**: 3890-3897.

Sutcliffe, I.C. and Russell, R.R. 1995. Lipoproteins of gram-positive bacteria. *J. Bacteriol.* **177**: 1123-1128.

Svanborg, C., Hedlund, M., Connell, H., Agace, W., Duan, R.D., Nilsson, A. and Wullt, B. 1996. Bacterial adherence and mucosal cytokine responses. Receptors and transmembrane signaling. *Ann. N.Y. Acad. Sci.* **797**: 177-190.

Taguchi, H., Yamaguchi, H., Yamamoto, T. and Kamiya, S. 1996. Immuno-cytochemical localization of 60-kDa heat shock protein in *Vibrio cholera*. *Zentbl. Bakteriol.* **284**: 406-500.

Taylor, R.K., Miller, V.L., Furlong, D.B. and Melakano, J.J. 1987. Use of *phoA* gene fusions to identify a pilus colonization factor coordinately regulated with cholera toxin. *Proc. Natl. Acad. Sci. USA* **84**: 2833-2837.

Taylor, L.A. and Rose, R.E. 1988. A correction in the nucleotide sequence of the Tn903 kanamycin resistance determinant in pUC4K. *Nucl. Acids Res.* **16**: 358.

Thanassi, D.G. and Hultgen, S.J. 2000. Multiple pathways allow protein secretion across the bacterial outer membrane. *Curr. Opin. Cell. Biol.* **12**: 420-430.

Thanassi, D.G., Saulino, E.T. and Hultgren, S.J. 1998. The chaperone/usher pathway: A major terminal branch of the general secretory pathway. *Curr. Opin. Microbiol.* **1**: 223-231.

- Thanassi, D.G., Saulino, E.T., Lombardo, M-J., Roth, R., Heuser, J. and Hultgren, S.J.** 1998. The PapC usher forms an oligomeric channel: Implications for pilus biogenesis across the outer membrane. *Proc. Natl. Acad. Sci. USA.* **95:** 3146-3151.
- Thanassi, D.G., Stathopoulos, C., Dodson, K., Geiger, D. and Hultgren, S.J.** 2002. Bacterial outer membrane ushers contain distinct targeting and assembly domains for pilus biogenesis. *J. Bacteriol.* **184:** 6260-6069.
- Thelin, K.H. and Taylor, R.K.** 1996. Toxin-coregulated pilus, but not mannose-sensitive hemagglutinin, is required for colonization by *Vibrio cholerae* O1 El Tor biotype and O139 strains. *Infect. Immun.* **64:** 2853-2856.
- Thomas, J.G., Ayling, A. and Baneyx, F.** 1997. Molecular chaperones, folding catalysts and the recovery of active recombinant proteins from *E. coli* to fold or to refold. *Appl. Biochem. Biotechnol.* **66:** 197-238.
- Thompson, J.D., Higgins, D.G. and Gibson, T.J.** 1994. CLUSTALW: Improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice. *Nucl. Acids Res.* **22:** 4673-4680.
- Thomson, V.J., Bhattacharjee, M.K., Fine, D.H., Derbyshire, K.M. and Figurski, D.H.** 1999. Direct selection of IS903 transposon insertions by use of a broad-host-range vector: Isolation of catalase-deficient mutants of *Actinobacillus actinomycetemcomitans*. *J. Bacteriol.* **181:** 7298-7307.
- Tolker-Nielsen, T., Brinch, U.C., Ragas, P.C., Andersen, J.B., Jacobsen, C.S. and Molin, S.** 2000. Development and dynamics of *Pseudomonas* sp. biofilm. *J. Bacteriol.* **182:** 6482-6489.
- Tønsum, T. and Koomey, M.** 1997. The pilus colonization factor of pathogenic neisserial species: Organelle biogenesis and structure/function relationships - a review. *Gene* **192:** 155-163.
- Trees, D.L. and Morse, S.A.** 1995. Chancroid and *Haemophilus ducreyi*: An update. *Clin. Microbiol. Rev.* **8:** 357-375.
- Turner, L.R., Lara, J.C., Nunn, D.N. and Lory, S.** 1993. Mutation in the consensus ATP-binding sites of XcpR and PilB eliminate extracellular protein secretion and pilus biogenesis in *Pseudomonas aeruginosa*. *J. Bacteriol.* **175:** 4962-4969.
- Valent, Q.A., Zaal, J., de Graaf, F.K. and Oudega, B.** 1995. Subcellular localization and topology of the K88 usher FaeD in *Escherichia coli*. *Mol. Microbiol.* **16:** 1243-1257.
- Vallet, I., Olson, J.W., Lory, S., Lazdunski, A. and Filloux, A.** 2001. The chaperone/usher pathways of *Pseudomonas aeruginosa*: Identification of fimbrial gene clusters (*cup*) and their involvement in biofilm formation. *Proc. Natl. Acad. Sci. USA* **98:** 6911-6916.
- Van Delden, C. and Iglesias, B.H.** 1998. Cell-to-cell signaling and *Pseudomonas aeruginosa* infections. *Emerg. Infect. Dis.* **4:** 551-560.
- Van Loosdrecht, M.C.M., Lyklema, J., Norde, W. and Zehnder, A.J.B.** 1990. Influence of interfaces on microbial activity. *Microbiol. Rev.* **54:** 75-87.
- Van Rosmalen, M. and Saier, M.H.** 1993. Structural and evolutionary relationships between two families of bacterial extracytoplasmic chaperone proteins which function cooperatively in fimbrial assembly. *Res. Microbiol.* **144:** 507-527.

- Vidal, O.L., Prigent-Combaret, R.C., Dorel, C., Hooreman, M. and Lejune, P.** 1998. Isolation of an *Escherichia coli* K-12 mutant strain able to form biofilms on inert surfaces: Involvement of a new *ompR* allele that increases curli expression. *J. Bacteriol.* **180**: 2442-2449.
- Walker, J.E., Saraste, M., Runswick, M.J. and Gay, N.J.** 1982. Distantly related sequences in the α - and β -subunits of ATP synthase, myosin, kinases and other ATP-requiring enzymes and a common nucleotide binding fold. *EMBO J.* **1**: 945-951.
- Wall, D. and Kaiser, D.** 1999. Type IV pili and cell motility. *Mol. Microbiol.* **32**: 1-10.
- Watnick, P.I., Fullner, K.J. and Kolter, R.** 1999. A role for the mannose-sensitive hemagglutinin in biofilm formation by *Vibrio cholerae* El Tor. *J. Bacteriol.* **181**: 3606-3609.
- Watnick, P.I. and Kolter, R.** 1999. Steps in the development of a *Vibrio cholerae* biofilm. *Mol. Microbiol.* **34**: 586-595.
- Watnick, P.I. and Kolter, R.** 2000. Biofilm, city of microbes. *J. Bacteriol.* **182**: 2675-2679.
- Watson, K.** 1990. Microbial stress proteins. *Adv. Microbiol. Physiol.* **31**: 183-223.
- Watson, A., Alm, R.A. and Mattick, J.S.** 1996a. Identification of a gene, *pilF*, that is required for type 4 fimbrial biogenesis and twitching motility in *Pseudomonas aeruginosa*. *Gene* **180**: 49-56.
- Watson, A., Alm, R.A. and Mattick, J.S.** 1996b. Functional expression of heterologous type 4 fimbriae in *Pseudomonas aeruginosa*. *Gene* **175**: 143-150.
- Weisburg, W.G., Barns, S.M., Pelletier, D.A. and Lane, D.J.** 1991. 16S Ribosomal DNA amplification for phylogenetic study. *J. Bacteriol.* **173**: 697-703.
- Wessel, D. and Flugge, U.I.** 1984. A method for the quantitative recovery of proteins in dilute solution in the presence of detergents and lipids. *Anal. Biochem.* **138**: 141-143.
- Whitchurch, C.B., Hobbs, M., Livingston, S.P., Krishnapillai, V. and Mattick, J.S.** 1991. Characterization of a *Pseudomonas aeruginosa* twitching motility gene and evidence for a specialized protein export system widespread in eubacteria. *Gene* **101**: 33-44.
- Whitchurch, C.B. and Mattick, J.S.** 1994. Characterization of a gene *pilU* required for twitching motility but not phage sensitivity in *Pseudomonas aeruginosa*. *Mol. Microbiol.* **13**: 1079-1091.
- Whiteley, M., Bangera, M.G., Bumgarner, R.E., Parsek, M.R., Teitzel, G.M., Lory, S. and Greenberg, E.P.** 2001. Gene expression in *Pseudomonas aeruginosa* biofilms. *Nature* **413**: 860-864.
- Whiteley, M. and Greenberg, E.P.** 2001. Promoter specificity elements in *Pseudomonas aeruginosa* quorum-sensing controlled genes. *J. Bacteriol.* **183**: 5529-5534.
- Whitmire, W.M. and Garon, C.F.** 1993. Specific and nonspecific responses of murine B cells to membrane blebs of *Borrelia burgdorferi*. *Infect. Immun.* **61**: 1460-1467.
- Wispelwey, B., Hansen, E.J. and Scheld, W.M.** 1989. *Haemophilus influenzae* outer membrane vesicle-induced blood-brain barrier permeability during experimental meningitis. *Infect. Immun.* **57**: 2559-2562.
- Wizemann, T.M., Adamou, J.E. and Langermann, S.** 1999. Adhesins as targets for vaccine development. *Emerg. Infect. Dis.* **5**: 395-403.

Wu, S.S., Wu, J. and Kaiser, D. 1997. The *Myxococcus xanthus* *pilT* locus is required for social gliding motility although pili are still produced. *Mol. Microbiol.* **23**: 109-121.

Yu, J., Weeb, H. and Hirst, T.R. 1992. A homologue of the *Escherichia coli* DsbA protein involved in disulphide bond formation is required for enterotoxin biogenesis in *Vibrio cholerae*. *Mol. Microbiol.* **6**: 1949-1958.

Zeilstra-Ryalls, J., Fayet, O. and Georgopoulos, C. 1991. The universally conserved GroE (Hsp60) chaperonins. *Annu. Rev. Microbiol.* **45**: 301-325.

Zhang, H.Z. and Donnenberg, M.S. 1996. DsbA is required for stability of the type IV pilus of enteropathogenic *Escherichia coli*. *Mol. Microbiol.* **21**: 787-797.

Zhang, J.P. and Normark, S. 1996. Induction of gene expression in *Escherichia coli* after pilus-mediated adherence. *Science* **273**: 1234-1236.

Zottola, E.A. and Sasahara, K.C. 1994. Microbial biofilms in the food processing industry - should they be a concern? *Int. J. Food Microbiol.* **32**: 125-148.