

## 6. LITERATURVERZEICHNIS

- Adaikkalam, V. und S. Swarup.** 2002. Molecular characterization of an operon, *cueAR*, encoding a putative P1-type ATPase and a MerR-type regulatory protein involved in copper homeostasis in *Pseudomonas putida*. *Microbiology* **148**(9):2857-67.
- Agranoff, D. D. und S. Krishna.** 1998. Metal ion homeostasis and intracellular parasitism. *Mol Microbiol* **28**(3):403-12.
- Akada, R.** 1994. Quick-Check method to test the size of *Escherichia coli* plasmids. *Biotechniques* **17**:58.
- Altschul, S. F., T. L. Madden, A. A. Schaffer, J. Zhang, Z. Zhang, W. Miller und D. J. Lipman.** 1997. Gapped BLAST and PSI-BLAST: a new generation of protein database search programs. *Nucleic Acids Res* **25**(17):3389-402.
- Anton, A.** 2001. Genetische und biochemische Charakterisierung von CzcD und anderen Regulatoren der *czc*-vermittelten Schwermetallresistenz in *Ralstonia metallidurans*. Dissertation. Martin-Luther-Universität Halle-Wittenberg, Halle.
- Anton, A., C. Grosse, J. Reissmann, T. Pribyl und D. H. Nies.** 1999. CzcD is a heavy metal ion transporter involved in regulation of heavy metal resistance in *Ralstonia* sp. strain CH34. *J Bacteriol* **181**(22):6876-81.
- Arnesano, F., L. Banci, I. Bertini, S. Ciofi-Baffoni, E. Molteni, D. L. Huffman und T. V. O'Halloran.** 2002. Metallochaperones and metal-transporting ATPases: a comparative analysis of sequences and structures. *Genome Res* **12**(2):255-71.
- Ausubel, F. M., R. Brent, R. E. Kingston, D. D. Moore, J. G. Sedman, J. A. Smith und K. Struhl.** 1993. Current protocols in molecular biology, Sec. Edition ed. Green Publishing Associates and John Wiley & Sons Inc., New York.
- Avila-Sakar, A. J., S. Misaghi, E. M. Wilson-Kubalek, K. H. Downing, H. Zgurskaya, H. Nikaido und E. Nogales.** 2001. Lipid-layer crystallization and preliminary three-dimensional structural analysis of AcrA, the periplasmic component of a bacterial multidrug efflux pump. *J Struct Biol* **136**(1):81-8.
- Axelsen, K. B. und M. G. Palmgren.** 1998. Evolution of substrate specificities in the P-type ATPase superfamily. *J Mol Evol* **46**(1):84-101.
- Bal, N., E. Mintz, F. Guillain und P. Catty.** 2001. A possible regulatory role for the metal-binding domain of CadA, the *Listeria monocytogenes* Cd<sup>2+</sup>-ATPase. *FEBS Lett* **506**(3):249-52.
- Bal, N., C. C. Wu, P. Catty, F. Guillain und E. Mintz.** 2003. Cd<sup>2+</sup> and the N-terminal metal-binding domain protect the putative membranous CPC motif of the Cd<sup>2+</sup>-ATPase of *Listeria monocytogenes*. *Biochem J* **369**(3):681-5.
- Banci, L., I. Bertini, S. Ciofi-Baffoni, L. A. Finney, C. E. Outten und T. V. O'Halloran.** 2002. A new zinc-protein coordination site in intracellular metal trafficking: solution structure of the Apo and Zn(II) forms of ZntA(46-118). *J Mol Biol* **323**(5):883-97.
- Barrineau, P., P. Gilbert, W. J. Jackson, C. S. Jones, A. O. Summers und S. Wisdom.** 1984. The DNA sequence of the mercury resistance operon of the IncFII plasmid NR1. *J Mol Appl Genet* **2**(6):601-19.

- Bayle, D., S. Wangler, T. Weitzenegger, W. Steinhilber, J. Volz, M. Przybylski, K. P. Schafer, G. Sachs und K. Melchers. 1998. Properties of the P-type ATPases encoded by the *copAP* operons of *Helicobacter pylori* and *Helicobacter felis*. *J Bacteriol* **180**(2):317-29.
- Bayle, D., D. Weeks, S. Hallen, K. Melchers, K. Bamberg und G. Sachs. 1997. *In vitro* translation analysis of integral membrane proteins. *J Recept Signal Transduct Res* **17**(1-3):29-56.
- Beard, S. J., R. Hashim, J. Membrillo-Hernandez, M. N. Hughes und R. K. Poole. 1997. Zinc(II) tolerance in *Escherichia coli* K-12: evidence that the *zntA* gene (o732) encodes a cation transport ATPase. *Mol Microbiol* **25**(5):883-91.
- Beard, S. J., R. Hashim, G. Wu, M. R. Binet, M. N. Hughes und R. K. Poole. 2000. Evidence for the transport of zinc(II) ions via the pit inorganic phosphate transport system in *Escherichia coli*. *FEMS Microbiol Lett* **184**(2):231-5.
- Bensadoun, A. und D. Weinstein. 1976. Assay of proteins in the presence of interfering materials. *Anal Biochem* **70**(1):241-50.
- Berg, J. M. und Y. Shi. 1996. The galvanization of biology: a growing appreciation for the roles of zinc. *Science* **271**(5252):1081-5.
- Binet, M. R. und R. K. Poole. 2000. Cd(II), Pb(II) and Zn(II) ions regulate expression of the metal-transporting P-type ATPase ZntA in *Escherichia coli*. *FEBS Lett* **473**(1):67-70.
- Bissig, K. D., H. Wunderli-Ye, P. W. Duda und M. Solioz. 2001. Structure-function analysis of purified *Enterococcus hirae* CopB copper ATPase: effect of Menkes/Wilson disease mutation homologues. *Biochem J* **357**(1):217-23.
- Blake, M. S., K. H. Johnston, G. J. Russell-Jones und E. C. Gotschlich. 1984. A rapid, sensitive method for detection of alkaline phosphatase-conjugated anti-antibody on Western blots. *Anal Biochem* **136**(1):175-9.
- Blattner, F. R., G. Plunkett, 3rd, C. A. Bloch, N. T. Perna, V. Burland, M. Riley, J. Collado-Vides, J. D. Glasner, C. K. Rode, G. F. Mayhew, J. Gregor, N. W. Davis, H. A. Kirkpatrick, M. A. Goeden, D. J. Rose, B. Mau und Y. Shao. 1997. The complete genome sequence of *Escherichia coli* K-12. *Science* **277**(5331):1453-74.
- Blencowe, D. K. und A. P. Morby. 2003. Zn(II) metabolism in prokaryotes. *FEMS Microbiol Rev* **27**(2-3):291-311.
- Blindauer, C. A., M. D. Harrison, A. K. Robinson, J. A. Parkinson, P. W. Bowness, P. J. Sadler und N. J. Robinson. 2002. Multiple bacteria encode metallothioneins and SmtA-like zinc fingers. *Mol Microbiol* **45**(5):1421-32.
- Borremans, B., J. L. Hobman, A. Provoost, N. L. Brown und D. van Der Lelie. 2001. Cloning and functional analysis of the *pbr* lead resistance determinant of *Ralstonia metallidurans* CH34. *J Bacteriol* **183**(19):5651-8.
- Bradford, M. M. 1976. A rapid and sensitive method for quantitation of microgramm quantities of protein utilizing the principle of protein-dye binding. *Anal Biochem* **72**:248-54.
- Brim, H., M. Heyndrickx, P. de Vos, A. Wilmotte, D. Springael, H. G. Schlegel und M. Mergeay. 1999. Amplified rDNA restriction analysis and further genotypic characterisation of metal-resistant soil bacteria and related facultative hydrogenotrophs. *Syst Appl Microbiol* **22**(2):258-68.

- Brocklehurst, K. R., J. L. Hobman, B. Lawley, L. Blank, S. J. Marshall, N. L. Brown und A. P. Morby.** 1999. ZntR is a Zn(II)-responsive MerR-like transcriptional regulator of *zntA* in *Escherichia coli*. *Mol Microbiol* **31**(3):893-902.
- Brown, N. L., S. J. Ford, R. D. Pridmore und D. C. Fritzing.** 1983. Nucleotide sequence of a gene from the *Pseudomonas* transposon Tn501 encoding mercuric reductase. *Biochemistry* **22**(17):4089-95.
- Brown, N. L., J. V. Stoyanov, S. P. Kidd und J. L. Hobman.** 2003. The MerR family of transcriptional regulators. *FEMS Microbiol Rev* **27**(2-3):145-63.
- Bull, P. C., G. R. Thomas, J. M. Rommens, J. R. Forbes und D. W. Cox.** 1993. The Wilson disease gene is a putative copper transporting P-type ATPase similar to the Menkes gene. *Nat Genet* **5**(4):327-37.
- Busenlehner, L. S., M. A. Pennella und D. P. Giedroc.** 2003. The SmtB/ArsR family of metalloregulatory transcriptional repressors: structural insights into prokaryotic metal resistance. *FEMS Microbiol Rev* **27**(2-3):131-43.
- Chamngopol, S. und E. A. Groisman.** 2002. Mg<sup>2+</sup> homeostasis and avoidance of metal toxicity. *Mol Microbiol* **44**(2):561-71.
- Chen, C. Y. und S. A. Morse.** 2001. Identification and characterization of a high-affinity zinc uptake system in *Neisseria gonorrhoeae*. *FEMS Microbiol Lett* **202**(1):67-71.
- Christie, G. E., T. J. White und T. S. Goodwin.** 1994. A *merR* homologue at 74 minutes on the *Escherichia coli* genome. *Gene* **146**(1):131-2.
- Coleman, J. E.** 1998. Zinc enzymes. *Curr Opin Chem Biol* **2**(2):222-34.
- Dalet, K., E. Gouin, Y. Cenatiempo, P. Cossart und Y. Hechard.** 1999. Characterisation of a new operon encoding a Zur-like protein and an associated ABC zinc permease in *Listeria monocytogenes*. *FEMS Microbiol Lett* **174**(1):111-6.
- Daniels, M. J., J. S. Turner-Cavet, R. Selkirk, H. Sun, J. A. Parkinson, P. J. Sadler und N. J. Robinson.** 1998. Coordination of Zn<sup>2+</sup> (and Cd<sup>2+</sup>) by prokaryotic metallothionein. Involvement of his-imidazole. *J Biol Chem* **273**(36):22957-61.
- de Meis, L. und A. L. Vianna.** 1979. Energy interconversion by the Ca<sup>2+</sup>-dependent ATPase of the sarcoplasmic reticulum. *Annu Rev Biochem* **48**:275-92.
- deHaseh, P. L., M. L. Zupancic und M. T. Record, Jr.** 1998. RNA polymerase-promoter interactions: the comings and goings of RNA polymerase. *J Bacteriol* **180**(12):3019-25.
- Deretic, V., S. Chandrasekharappa, J. F. Gill, D. K. Chatterjee und A. M. Chakrabarti.** 1987. A set of cassettes and improved vectors for genetic and biochemical characterization of *Pseudomonas* genes. *Gene* **57**(1):61-72.
- DiDonato, M., S. Narindrasorasak, J. R. Forbes, D. W. Cox und B. Sarkar.** 1997. Expression, purification, and metal binding properties of the N-terminal domain from the wilson disease putative copper-transporting ATPase (ATP7B). *J Biol Chem* **272**(52):33279-82.
- Diels, L., Q. Dong, D. van der Lelie, W. Baeyens und M. Mergeay.** 1995. The *czc* operon of *Alcaligenes eutrophus* CH34: from resistance mechanism to the removal of heavy metals. *J Ind Microbiol* **14**(2):142-53.
- Diels, L., M. Faelen, M. Mergeay und D. H. Nies.** 1985. Mercury transposons from plasmids governing multiple resistance to heavy metals in *Alcaligenes eutrophus* CH34. *Arch Int Physiol Biochim* **93**:B27-B28.

- Dinh, T., I. T. Paulsen und M. H. Saier, Jr.** 1994. A family of extracytoplasmic proteins that allow transport of large molecules across the outer membranes of gram-negative bacteria. *J Bacteriol* **176**(13):3825-31.
- Dressler, C., U. Kües, D. H. Nies und B. Friedrich.** 1991. Determinants encoding resistance to several heavy metals in newly isolated copper-resistant bacteria. *Appl Environ Microbiol* **57**:3079-85.
- Elkins, C. A. und H. Nikaido.** 2002. Substrate specificity of the RND-type multidrug efflux pumps AcrB and AcrD of *Escherichia coli* is determined predominantly by two large periplasmic loops. *J Bacteriol* **184**(23):6490-8.
- Elkins, C. A., und H. Nikaido.** 2003. Chimeric analysis of AcrA function reveals the importance of its c-terminal domain in its interaction with the AcrB multidrug efflux pump. *J Bacteriol* **185**(18):5349-56.
- Endo, G. und S. Silver.** 1995. CadC, the transcriptional regulatory protein of the cadmium resistance system of *Staphylococcus aureus* plasmid pI258. *J Bacteriol* **177**(15):4437-41.
- Eng, B. H., M. L. Guerinot, D. Eide und M. H. Saier, Jr.** 1998. Sequence analyses and phylogenetic characterization of the ZIP family of metal ion transport proteins. *J Membr Biol* **166**(1):1-7.
- Fairbanks, G. und J. Avruch.** 1972. Four gel systems for electrophoretic fractionation of membrane proteins using ionic detergents. *J Supramol Struct* **1**(1):66-75.
- Fan, B., G. Grass, C. Rensing, und B. P. Rosen.** 2001. *Escherichia coli* CopA N-terminal Cys(X)<sub>2</sub>Cys motifs are not required for copper resistance or transport. *Biochem Biophys Res Commun* **286**:414-8.
- Franke, S., G. Grass, D. H. Nies.** 2001. The product of the ybdE gene of the *Escherichia coli* chromosome is involved in detoxification of silver ions. *Microbiol* **147**(4):965-72.
- Franke, S., G. Grass, C. Rensing und D. H. Nies.** 2003. Molecular analysis of the copper-transporting efflux system CusCFBA of *Escherichia coli*. *J Bacteriol* **185**(13):3804-12.
- Fuhr, B. J. und D. L. Rabenstein.** 1973. Nuclear magnetic resonance studies of the solution chemistry of metal complexes. IX. The binding of cadmium, zinc, lead, and mercury by glutathione. *J Am Chem Soc* **95**(21):6944-50.
- Fujihira, E., N. Tamura und A. Yamaguchi.** 2002. Membrane topology of a multidrug efflux transporter, AcrB, in *Escherichia coli*. *J Biochem (Tokyo)* **131**(1):145-51.
- Gaither, L. A. und D. J. Eide.** 2001. Eukaryotic zinc transporters and their regulation. *Biometals* **14**(3-4):251-70.
- Gatti, D., B. Mitra und B. P. Rosen.** 2000. *Escherichia coli* soft metal ion-translocating ATPases. *J Biol Chem* **275**(44):34009-12.
- Goldberg, M., T. Pribyl, S. Juhnke und D. H. Nies.** 1999. Energetics and topology of CzcA, a cation/proton antiporter of the resistance-nodulation-cell division protein family. *J Biol Chem* **274**(37):26065-70.
- Goris, J., P. De Vos, T. Coenye, B. Hoste, D. Janssens, H. Brim, L. Diels, M. Mergeay, K. Kersters und P. Vandamme.** 2001. Classification of metal-resistant bacteria from industrial biotopes as *Ralstonia campinensis* sp. nov., *Ralstonia metallidurans* sp. nov. and *Ralstonia basilensis* Steinle et al. 1998 emend. *Int J Syst Evol Microbiol* **51**(5):1773-82.

- Gotoh, N., T. Kusumi, H. Tsujimoto, T. Wada und T. Nishino.** 1999. Topological analysis of an RND family transporter, MexD of *Pseudomonas aeruginosa*. *FEBS Lett* **458**(1):32-6.
- Grass, G.** 2000. Molekulargenetische und biochemische Charakterisierung der *cnr* Cobalt/Nickel-Resistenz-Determinante aus *Ralstonia metallidurans* CH34. Dissertation. Martin-Luther-Universität Halle-Wittenberg, Halle.
- Grass, G., B. Fan, B. P. Rosen, S. Franke, D. H. Nies und C. Rensing.** 2001. ZitB (YbgR), a member of the cation diffusion facilitator family, is an additional zinc transporter in *Escherichia coli*. *J Bacteriol* **183**(15):4664-7.
- Grass, G., C. Grosse und D. H. Nies.** 2000. Regulation of the *cnr* cobalt and nickel resistance determinant from *Ralstonia* sp. strain CH34. *J Bacteriol* **182**(5):1390-8.
- Grass, G., und C. Rensing.** 2001a. CueO is a multi-copper oxidase that confers copper tolerance in *Escherichia coli*. *Biochem Biophys Res Commun* **286**(5):902-8.
- Grass, G. und C. Rensing.** 2001b. Genes involved in copper homeostasis in *Escherichia coli*. *J Bacteriol* **183**(6):2145-7.
- Grass, G., M. D. Wong, B. P. Rosen, R. L. Smith, und C. Rensing.** 2002. ZupT is a Zn(II) uptake system in *Escherichia coli*. *J Bacteriol* **184**(3):864-6.
- Grosse, C., A. Anton, T. Hoffmann, S. Franke, G. Schleuder, und D. Nies.** Regulation of the metal resistance determinant *czc* from *Ralstonia metallidurans* by the four proteins CzcD, CzcR, CzcS, and CzcE. In Vorbereitung.
- Grosse, C., G. Grass, A. Anton, S. Franke, A. N. Santos, B. Lawley, N. L. Brown und D. H. Nies.** 1999. Transcriptional organization of the *czc* heavy-metal homeostasis determinant from *Alcaligenes eutrophus*. *J Bacteriol* **181**(8):2385-93.
- Guerinot, M. L.** 2000. The ZIP family of metal transporters. *Biochim Biophys Acta* **1465**(1-2):190-8.
- Guffanti, A. A., Y. Wei, S. V. Rood und T. A. Krulwich.** 2002. An antiport mechanism for a member of the cation diffusion facilitator family: divalent cations efflux in exchange for  $K^+$  and  $H^+$ . *Mol Microbiol* **45**(1):145-53.
- Gunshin, H., B. Mackenzie, U. V. Berger, Y. Gunshin, M. F. Romero, W. F. Boron, S. Nussberger, J. L. Gollan und M. A. Hediger.** 1997. Cloning and characterization of a mammalian proton-coupled metal-ion transporter. *Nature* **388**(6641):482-8.
- Hamer, D. H.** 1986. Metallothionein. *Annu Rev Biochem* **55**:913-51.
- Hantke, K.** 2001. Bacterial zinc transporters and regulators. *Biometals* **14**(3-4):239-49.
- Hassan, M. T., D. van der Lelie, D. Springael, U. Romling, N. Ahmed und M. Mergeay.** 1999. Identification of a gene cluster, *czr*, involved in cadmium and zinc resistance in *Pseudomonas aeruginosa*. *Gene* **238**(2):417-25.
- Helbig, K.** 2003. Aufklärung der Funktion des Schwermetall-Transporters CzcA aus *Ralstonia metallidurans* CH34 durch gerichtete Mutagenese. Diplomarbeit. Martin-Luther-Universität Halle-Wittenberg, Halle.
- Henderson, P. J., C. K. Hoyle und A. Ward.** 2000. Expression, purification and properties of multidrug efflux proteins. *Biochem Soc Trans* **28**(4):513-7.
- Herrmann, L., D. Schwan, R. Garner, H. L. Mobley, R. Haas, K. P. Schafer und K. Melchers.** 1999. *Helicobacter pylori* *cadA* encodes an essential Cd(II)-Zn(II)-Co(II) resistance factor influencing urease activity. *Mol Microbiol* **33**(3):524-36.
- Hess, H. H., M. B. Lees und J. E. Derr.** 1978. A linear Lowry--Folin assay for both water-soluble and sodium dodecyl sulfate-solubilized proteins. *Anal Biochem* **85**(1):295-300.

- Higgs, P. I., P. S. Myers und K. Postle.** 1998. Interactions in the TonB-dependent energy transduction complex: ExhB and ExhD from homomultimers. *J Bacteriol* **180**(22):6031-8.
- Higham, D. P., P. J. Sadler und M. D. Scawen.** 1986. Cadmium-binding proteins in *Pseudomonas putida*: pseudothioneins. *Environ Health Perspect* **65**:5-11.
- Hitomi, Y., C. E. Outten und T. V. O'Halloran.** 2001. Extreme zinc-binding thermodynamics of the metal sensor/regulator protein, ZntR. *J Am Chem Soc* **123**(35):8614-5.
- Hmiel, S. P., M. D. Snavely, J. B. Florer, M. E. Maguire und C. G. Miller.** 1989. Magnesium transport in *Salmonella typhimurium*: genetic characterization and cloning of three magnesium transport loci. *J Bacteriol* **171**(9):4742-51.
- Hoffmann, T.** 2001. Untersuchung der Regulation der Schwermetallresistenz in *R. metallidurans* CH34 durch Zweidimensionale Gelelektrophorese und Reporterfusion. Diplomarbeit. Martin-Luther-Universität Halle-Wittenberg, Halle.
- Hou, Z., und B. Mitra.** 2003. The metal specificity and selectivity of ZntA from *Escherichia coli* using the acylphosphate intermediate. *J Biol Chem* **278**(31):28455-61.
- Hou, Z. J., S. Narindrasorasak, B. Bhushan, B. Sarkar und B. Mitra.** 2001. Functional analysis of chimeric proteins of the Wilson Cu(I)-ATPase (ATP7B) and ZntA, a Pb(II)/Zn(II)/Cd(II)-ATPase from *Escherichia coli*. *J Biol Chem* **276**(44):40858-63.
- Hsu, C. M. und B. P. Rosen.** 1989. Characterization of the catalytic subunit of an anion pump. *J Biol Chem* **264**(29):17349-54.
- Hughes, M. N. und R. K. Poole.** 1991. Metal speciation and microbial growth - the hard (and soft) facts. *J Gen Microbiol* **137**:725-34.
- Hultberg, M.** 1998. Rhizobacterial glutathione levels as affected by starvation and cadmium exposure. *Curr Microbiol* **37**(5):301-5.
- Huster, D., und S. Lutsenko.** 2003. The Distinct Roles of the N-terminal Copper-binding Sites in Regulation of Catalytic Activity of the Wilson's Disease Protein. *J Biol Chem* **278**(34):32212-8.
- Jamieson, D.** 2002. Saving sulfur. *Nat Genet* **31**(3):228-30.
- Jasper, P. und S. Silver.** 1997. Magnesium transport in microorganisms, p. 7-45. In E. D. Weinberg, Ed (ed.), In: Microorganisms and Minerals, vol. 3. Marcel Dekker, New York.
- Jin, Y. H., A. B. Clark, R. J. Slebos, H. Al-Refai, J. A. Taylor, T. A. Kunkel, M. A. Resnick und D. A. Gordenin.** 2003. Cadmium is a mutagen that acts by inhibiting mismatch repair. *Nat Genet* **34**(3):326-9.
- Johnson, J. L.** 1981. Genetic characterization, p. 450-72. In P. Gerhardt (ed.), Manual of Methods of General Bacteriology. ASM, Washington.
- Johnson, J. M. und G. M. Church.** 1999. Alignment and structure prediction of divergent protein families: periplasmic and outer membrane proteins of bacterial efflux pumps. *J Mol Biol* **287**(3):695-715.
- Juhnke, S.** 1997. Einfluß von Punktmutationen im *czcA*-Gen auf die Funktion des CzcA-Proteins. Diplomarbeit. Martin-Luther-Universität Halle-Wittenberg, Halle.
- Juhnke, S., N. Peitzsch, N. Hubener, C. Grosse und D. H. Nies.** 2002. New genes involved in chromate resistance in *Ralstonia metallidurans* strain CH34. *Arch Microbiol* **179**(1):15-25.

- Karlin, S. und Z. Y. Zhu.** 1997. Classification of mononuclear zinc metal sites in protein structures. *Proc Natl Acad Sci U S A* **94**(26):14231-6.
- Kawabe, T., E. Fujihira und A. Yamaguchi.** 2000. Molecular construction of a multidrug exporter system, AcrAB: molecular interaction between AcrA and AcrB, and cleavage of the N-terminal signal sequence of AcrA. *J Biochem (Tokyo)* **128**(2):195-200.
- Kehres, D. G., M. L. Zaharik, B. B. Finlay und M. E. Maguire.** 2000. The NRAMP proteins of *Salmonella typhimurium* and *Escherichia coli* are selective manganese transporters involved in the response to reactive oxygen. *Mol Microbiol* **36**(5):1085-100.
- Khan, S., K. R. Brocklehurst, G. W. Jones und A. P. Morby.** 2002. The functional analysis of directed amino-acid alterations in ZntR from *Escherichia coli*. *Biochem Biophys Res Commun* **299**(3):438-45.
- Kidd, S. P. und N. L. Brown.** 2003. ZccR--a MerR-like regulator from *Bordetella pertussis* which responds to zinc, cadmium, and cobalt. *Biochem Biophys Res Commun* **302**(4):697-702.
- Koronakis, V., A. Sharff, E. Koronakis, B. Luisi und C. Hughes.** 2000. Crystal structure of the bacterial membrane protein TolC central to multidrug efflux and protein export. *Nature* **405**(6789):914-9.
- Kyte, J. und R. F. Doolittle.** 1982. A simple method for displaying the hydropathic character of a protein. *J Mol Biol* **157**(1):105-32.
- Laemmli, U. K.** 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* **227**(259):680-5.
- Lane, T. W. und F. M. Morel.** 2000. A biological function for cadmium in marine diatoms. *Proc Natl Acad Sci U S A* **97**(9):4627-31.
- Lee, S. M., G. Grass, C. J. Haney, B. Fan, B. P. Rosen, A. Anton, D. H. Nies und C. Rensing.** 2002. Functional analysis of the *Escherichia coli* zinc transporter ZitB. *FEMS Microbiol Lett* **215**(2):273-8.
- Lee, S. W., E. Glickmann und D. A. Cooksey.** 2001. Chromosomal locus for cadmium resistance in *Pseudomonas putida* consisting of a cadmium-transporting ATPase and a MerR family response regulator. *Appl Environ Microbiol* **67**(4):1437-44.
- Legatzki, A., S. Franke, S. Lucke, T. Hoffmann, A. Anton, D. Neumann, und D. H. Nies.** 2003a. First step towards a quantitative model describing Czc-mediated heavy metal resistance in *Ralstonia metallidurans*. *Biodegradation* **14**(2):153-68.
- Legatzki, A., G. Grass, A. Anton, C. Rensing, und D. H. Nies.** 2003b. Interplay of the Czc system and two P-type ATPases in conferring metal resistance to *Ralstonia metallidurans*. *J Bacteriol* **185**(15):4354-61.
- Lenz, O., E. Schwartz, J. Dervedde, M. Eitinger und B. Friedrich.** 1994. The *Alcaligenes eutrophus* H16 *hoxX* gene participates in hydrogenase regulation. *J Bacteriol* **176**(14):4385-93.
- Liesegang, H.** 1994. Die Kobalt- und Nickelresistenz (*cnr*) aus *Alcaligenes eutrophus* CH34: Nukleotidsequenz, beteiligte Gene und Genprodukte. Dissertation. Georg-August-Universität, Göttingen.
- Liesegang, H., K. Lemke, R. A. Siddiqui und H. G. Schlegel.** 1993. Characterization of the inducible nickel and cobalt resistance determinant *cnr* from pMOL28 of *Alcaligenes eutrophus* CH34. *J Bacteriol* **175**(3):767-78.

- Liu, T., S. Nakashima, K. Hirose, Y. Uemura, M. Shibasaka, M. Katsuhara, und K. Kasamo.** 2003. A metallothionein and CPx-ATPase handle heavy-metal tolerance in the filamentous cyanobacterium *Oscillatoria brevis*. *FEBS Lett* **542**(1-3):159-63.
- Lowry, O. H., A. L. Farr und R. J. Randall.** 1951. Protein measurement with the folin phenol reagent. *J Biol Chem* **193**:265-75.
- Lu, D., B. Boyd und C. A. Lingwood.** 1997. Identification of the key protein for zinc uptake in *Hemophilus influenzae*. *J Biol Chem* **272**(46):29033-8.
- Lund, P. A., S. J. Ford und N. L. Brown.** 1986. Transcriptional regulation of the mercury-resistance genes of transposon Tn501. *J Gen Microbiol* **132**(2):465-80.
- Lutsenko, S. und J. H. Kaplan.** 1995. Organization of P-type ATPases: significance of structural diversity. *Biochemistry* **34**(48):15607-13.
- Lutsenko, S., K. Petrukhin, T. C. Gilliam und J. H. Kaplan.** 1997. Heterologous expression of the metal-binding domains of human copper-transporting ATPases (P1-ATPases). *Ann N Y Acad Sci* **834**:155-7.
- Ma, D., D. N. Cook, M. Alberti, N. G. Pon, H. Nikaido und J. E. Hearst.** 1993. Molecular cloning and characterization of *acrA* and *acrE* genes of *Escherichia coli*. *J Bacteriol* **175**(19):6299-313.
- Ma, D., D. N. Cook, M. Alberti, N. G. Pon, H. Nikaido und J. E. Hearst.** 1995. Genes *acrA* and *acrB* encode a stress-induced efflux system of *Escherichia coli*. *Mol Microbiol* **16**(1):45-55.
- Makui, H., E. Roig, S. T. Cole, J. D. Helmann, P. Gros und M. F. Cellier.** 2000. Identification of the *Escherichia coli* K-12 Nramp orthologue (MntH) as a selective divalent metal ion transporter. *Mol Microbiol* **35**(5):1065-78.
- Mandel, M. und A. Higa.** 1970. Calcium dependent bacteriophage DNA infection. *J Mol Biol* **53**:159-62.
- Mao, W., M. S. Warren, D. S. Black, T. Satou, T. Murata, T. Nishino, N. Gotoh und O. Lomovskaya.** 2002. On the mechanism of substrate specificity by resistance nodulation division (RND)-type multidrug resistance pumps: the large periplasmic loops of MexD from *Pseudomonas aeruginosa* are involved in substrate recognition. *Mol Microbiol* **46**(3):889-901.
- McMurray, C. T. und J. A. Tainer.** 2003. Cancer, cadmium and genome integrity. *Nat Genet* **34**(3):239-41.
- Melchers, K., T. Weitzenegger, A. Buhmann, W. Steinhilber, G. Sachs und K. P. Schafer.** 1996. Cloning and membrane topology of a P-type ATPase from *Helicobacter pylori*. *J Biol Chem* **271**(1):446-57.
- Mergeay, M., C. Houba und J. Gerits.** 1978. Extrachromosomal inheritance controlling resistance to cadmium, cobalt, copper and zinc ions: evidence from curing in a *Pseudomonas* [proceedings]. *Arch Int Physiol Biochim* **86**(2):440-2.
- Mergeay, M., S. Monchy, T. Vallaey, V. Auquier, A. Benotmane, P. Bertin, S. Taghavi, J. Dunn, D. van der Lelie und R. Wattiez.** 2003. *Ralstonia metallidurans*, a bacterium specifically adapted to toxic metals: towards a catalogue of metal-responsive genes. *FEMS Microbiol Rev* **27**(2-3):385-410.
- Mergeay, M., D. Nies, H. G. Schlegel, J. Gerits, P. Charles und F. Van Gijsegem.** 1985. *Alcaligenes eutrophus* CH34 is a facultative chemolithotroph with plasmid-bound resistance to heavy metals. *J Bacteriol* **162**(1):328-34.
- Miller, J. H.** 1972. Experiments in molecular genetics. Cold Spring Harbor, New York.

- Mitra, B. und R. Sharma.** 2001. The cysteine-rich amino-terminal domain of ZntA, a Pb(II)/Zn(II)/Cd(II)-translocating ATPase from *Escherichia coli*, is not essential for its function. *Biochemistry* **40**(25):7694-9.
- Moller, J. V., B. Juul und M. le Maire.** 1996. Structural organization, ion transport, and energy transduction of P-type ATPases. *Biochim Biophys Acta* **1286**(1):1-51.
- Mosteller, R. D. und R. V. Goldstein.** 1975. Unusual sensitivity of *E. coli* to adenine or adenine plus histidine. *J Bacteriol* **123**(2):750-1.
- Murakami, S., R. Nakashima, E. Yamashita und A. Yamaguchi.** 2002. Crystal structure of bacterial multidrug efflux transporter AcrB. *Nature* **419**(6907):587-93.
- Nelson, D. L. und E. P. Kennedy.** 1971. Magnesium transport in *Escherichia coli*. Inhibition by cobaltous ion. *J Biol Chem* **246**(9):3042-9.
- Nesterenko, M. V., M. Tilley und S. J. Upton.** 1994. A simple modification of Blum's silver stain method allows for 30 minute detection of proteins in polyacrylamide gels. *J Biochem Biophys Methods* **28**(3):239-42.
- Nies, A., D. H. Nies und S. Silver.** 1989a. Cloning and expression of plasmid genes encoding resistances to chromate and cobalt in *Alcaligenes eutrophus*. *J Bacteriol* **171**(9):5065-70.
- Nies, A., D. H. Nies und S. Silver.** 1990. Nucleotide sequence and expression of a plasmid-encoded chromate resistance determinant from *Alcaligenes eutrophus*. *J Biol Chem* **265**(10):5648-53.
- Nies, D. H.** 1991. Effluxsysteme als Grundlage bakterieller Metallresistenzen. *Bioforum* **7-8**:251-6.
- Nies, D. H.** 1995. The cobalt, zinc, and cadmium efflux system CzcABC from *Alcaligenes eutrophus* functions as a cation-proton antiporter in *Escherichia coli*. *J Bacteriol* **177**(10):2707-12.
- Nies, D. H.** 1999. Microbial heavy-metal resistance. *Appl Microbiol Biotechnol* **51**(6):730-50.
- Nies, D. H.** 2000. Heavy metal-resistant bacteria as extremophiles: molecular physiology and biotechnological use of *Ralstonia* sp. CH34. *Extremophiles* **4**(2):77-82.
- Nies, D. H.** 2003. Efflux-mediated heavy metal resistance in prokaryotes. *FEMS Microbiol Rev* **27**(2-3):313-39.
- Nies, D. H., M. Mergeay, B. Friedrich und H. G. Schlegel.** 1987. Cloning of plasmid genes encoding resistance to cadmium, zinc, and cobalt in *Alcaligenes eutrophus* CH34. *J Bacteriol* **169**(10):4865-8.
- Nies, D. H., A. Nies, L. Chu und S. Silver.** 1989b. Expression and nucleotide sequence of a plasmid-determined divalent cation efflux system from *Alcaligenes eutrophus*. *Proc Natl Acad Sci U S A* **86**(19):7351-5.
- Nies, D. H. und S. Silver.** 1989a. Metal ion uptake by a plasmid-free metal-sensitive *Alcaligenes eutrophus* strain. *J Bacteriol* **171**(7):4073-5.
- Nies, D. H. und S. Silver.** 1989b. Plasmid-determined inducible efflux is responsible for resistance to cadmium, zinc, and cobalt in *Alcaligenes eutrophus*. *J Bacteriol* **171**(2):896-900.
- Nies, D. H. und S. Silver.** 1995. Ion efflux systems involved in bacterial metal resistances. *J Ind Microbiol* **14**(2):186-99.
- Nikaido, H., M. Basina, V. Nguyen, und E. Y. Rosenberg.** 1998. Multidrug efflux pump AcrAB of *Salmonella typhimurium* excretes only those beta-lactam antibiotics containing lipophilic side chains. *J Bacteriol* **180**(17):4686-92.

- Nucifora, G., L. Chu, T. K. Misra und S. Silver.** 1989. Cadmium resistance from *Staphylococcus aureus* plasmid pI258 *cadA* gene results from a cadmium-efflux ATPase. *Proc Natl Acad Sci U S A* **86**(10):3544-8.
- Odermatt, A., H. Suter, R. Krapf und M. Solioz.** 1993. Primary structure of two P-type ATPases involved in copper homeostasis in *Enterococcus hirae*. *J Biol Chem* **268**(17):12775-9.
- Okkeri, J. und T. Haltia.** 1999. Expression and mutagenesis of ZntA, a zinc-transporting P-type ATPase from *Escherichia coli*. *Biochemistry* **38**(42):14109-16.
- Outten, C. E. und T. V. O'Halloran.** 2001. Femtomolar sensitivity of metalloregulatory proteins controlling zinc homeostasis. *Science* **292**(5526):2488-92.
- Outten, C. E., F. W. Outten und T. V. O'Halloran.** 1999. DNA distortion mechanism for transcriptional activation by ZntR, a Zn(II)-responsive MerR homologue in *Escherichia coli*. *J Biol Chem* **274**(53):37517-24.
- Palmgren, M. G. und K. B. Axelsen.** 1998. Evolution of P-type ATPases. *Biochim Biophys Acta* **1365**(1-2):37-45.
- Patzer, S. I. und K. Hantke.** 1998. The ZnuABC high-affinity zinc uptake system and its regulator Zur in *Escherichia coli*. *Mol Microbiol* **28**(6):1199-210.
- Patzer, S. I. und K. Hantke.** 2000. The zinc-responsive regulator Zur and its control of the *znu* gene cluster encoding the ZnuABC zinc uptake system in *Escherichia coli*. *J Biol Chem* **275**(32):24321-32.
- Patzer, S. I. und K. Hantke.** 2001. Dual repression by Fe(2+)-Fur and Mn(2+)-MntR of the *mntH* gene, encoding an NRAMP-like Mn(2+) transporter in *Escherichia coli*. *J Bacteriol* **183**(16):4806-13.
- Paulsen, I. T., M. H. Brown und R. A. Skurray.** 1996. Proton-dependent multidrug efflux systems. *Microbiol Rev* **60**(4):575-608.
- Paulsen, I. T., J. H. Park, P. S. Choi und M. H. Saier, Jr.** 1997. A family of gram-negative bacterial outer membrane factors that function in the export of proteins, carbohydrates, drugs and heavy metals from gram-negative bacteria. *FEMS Microbiol Lett* **156**(1):1-8.
- Paulsen, I. T. und M. H. Saier, Jr.** 1997. A novel family of ubiquitous heavy metal ion transport proteins. *J Membr Biol* **156**(2):99-103.
- Peitzsch, N., G. Eberz und D. H. Nies.** 1998. *Alcaligenes eutrophus* as a bacterial chromate sensor. *Appl Environ Microbiol* **64**(2):453-8.
- Perrin, D. D. und A. E. Watt.** 1971. Complex formation of zinc and cadmium with glutathione. *Biochim Biophys Acta* **230**(1):96-104.
- Pfennig, N.** 1974. *Rhodopseudomonas globiformis* sp. n., a new species of *Rhodospirillaceae*. *Arch Microbiol* **100**:197-206.
- Pribyl, T.** 2001. Topologie des CzcCBA-Efflux-Komplexes aus *Ralstonia metallidurans*. Dissertation. Martin-Luther-Universität Halle-Wittenberg, Halle.
- Rabilloud, T., G. Carpentier und P. Tarroux.** 1988. Improvement and simplification of low-background silver staining of proteins by using sodium dithionite. *Electrophoresis* **9**(6):288-91.
- Ramos, J. L., P. Duque, P. Godoy und A. Segura.** 1998. Efflux pumps involved in toluene tolerance in *Pseudomonas putida* DOT-T1E. *J Bacteriol* **180**(13):3323-9.
- Rensing, C., B. Fan, R. Sharma, B. Mitra und B. P. Rosen.** 2000. CopA: An *Escherichia coli* Cu(I)-translocating P-type ATPase. *Proc Natl Acad Sci U S A* **97**(2):652-6.

- Rensing, C., und G. Grass.** 2003. *Escherichia coli* mechanisms of copper homeostasis in changing environment. *FEMS Microbiol Rev* **27**(2-3):197-213.
- Rensing, C., M. Ghosh und B. P. Rosen.** 1999. Families of soft-metal-ion-transporting ATPases. *J Bacteriol* **181**(19):5891-7.
- Rensing, C., B. Mitra und B. P. Rosen.** 1997a. The *zntA* gene of *Escherichia coli* encodes a Zn(II)-translocating P-type ATPase. *Proc Natl Acad Sci U S A* **94**(26):14326-31.
- Rensing, C., T. Pribyl und D. H. Nies.** 1997b. New functions for the three subunits of the CzcCBA cation-proton antiporter. *J Bacteriol* **179**(22):6871-9.
- Rensing, C., Y. Sun, B. Mitra und B. P. Rosen.** 1998. Pb(II)-translocating P-type ATPases. *J Biol Chem* **273**(49):32614-7.
- Riggle, P. J. und C. A. Kumamoto.** 2000. Role of a *Candida albicans* P1-type ATPase in resistance to copper and silver ion toxicity. *J Bacteriol* **182**(17):4899-905.
- Roberts, S. A., G. F. Wildner, G. Grass, A. Weichsel, A. Ambrus, C. Rensing, und W. R. Montfort.** 2003. A labile regulatory copper ion lies near the T1 copper site in the multicopper oxidase CueO. *J Biol Chem* **278**(34):31958-63.
- Rosen, B. P.** 1986. Recent advances in bacterial ion transport. *Annu Rev Microbiol* **40**:263-86.
- Rutherford, J. C., J. S. Cavet und N. J. Robinson.** 1999. Cobalt-dependent transcriptional switching by a dual-effector MerR-like protein regulates a cobalt-exporting variant CPx-type ATPase. *J Biol Chem* **274**(36):25827-32.
- Saier, M. H., Jr.** 2000a. A functional-phylogenetic classification system for transmembrane solute transporters. *Microbiol Mol Biol Rev* **64**(2):354-411.
- Saier, M. H., Jr.** 2000b. Vectorial metabolism and the evolution of transport systems. *J Bacteriol* **182**(18):5029-35.
- Saier, M. H., Jr., R. Tam, A. Reizer und J. Reizer.** 1994. Two novel families of bacterial membrane proteins concerned with nodulation, cell division and transport. *Mol Microbiol* **11**(5):841-7.
- Sambrook, J., E. F. Fritsch und T. Maniatis.** 1989. Molecular cloning: a laboratory manual, 2nd ed. Cold Spring Harbor, New York.
- Sanger, F., S. Nicklen und A. R. Coulson.** 1977. DNA-Sequencing with chain terminating inhibitors. *Proc Natl Acad Sci U S A* **74**(12):5463-67.
- Schmidt, T. und H. G. Schlegel.** 1994. Combined nickel-cobalt-cadmium resistance encoded by the *ncc* locus of *Alcaligenes xylosoxidans* 31A. *J Bacteriol* **176**(22):7045-54.
- Schultz, J., R. R. Copley, T. Doerks, C. P. Ponting und P. Bork.** 2000. SMART, A Web-based tool for the study of genetically mobile domains. *Nucleic Acids Res* **28**(1):231-34.
- Schultz, J., F. Milpetz, P. Bork und C. P. Ponting.** 1998. SMART, a simple modular architecture research tool: Identification of signalling domains. *Proc Natl Acad Sci U S A* **95**(11):5857.
- Schwuchow, T.** 1995. Expression der *czcD*-Genregion von *Alcaligenes eutrophus* CH34. Diplomarbeit. Martin-Luther-Universität Halle-Wittenberg, Halle.
- Sharma, R., C. Rensing, B. P. Rosen und B. Mitra.** 2000. The ATP hydrolytic activity of purified ZntA, a Pb(II)/Cd(II)/Zn(II)-translocating ATPase from *Escherichia coli*. *J Biol Chem* **275**(6):3873-8.

- Siddiqui, R. A., K. Benthin und H. G. Schlegel.** 1989. Cloning of pMOL28-encoded nickel resistance genes and expression of the genes in *Alcaligenes eutrophus* and *Pseudomonas* spp. *J Bacteriol* **171**(9):5071-8.
- Siddiqui, R. A., H. G. Schlegel und M. Meyer.** 1988. Inducible and constitutive expression of pMOL28-encoded nickel resistance in *Alcaligenes eutrophus* N9A. *J Bacteriol* **170**(9):4188-93.
- Simon, R., U. Priefer und A. Pühler.** 1983. A broad host range mobilization system for *in vivo* genetic engineering: Transposon mutagenesis in gram-negative bacteria. *Bio/Technology* **1**:784-91.
- Skare, J. T., B. M. Ahmer, C. L. Seachord, R. P. Darveau und K. Postle.** 1993. Energy transduction between membranes. TonB, a cytoplasmic membrane protein, can be chemically cross-linked *in vivo* to the outer membrane receptor FepA. *J Biol Chem* **268**(22):16302-8.
- Smith, R. L., L. J. Thompson und M. E. Maguire.** 1995. Cloning and characterization of MgtE, a putative new class of Mg<sup>2+</sup> transporter from *Bacillus firmus* OF4. *J Bacteriol* **177**(6):1233-8.
- Snively, M. D., J. B. Florer, C. G. Miller und M. E. Maguire.** 1989a. Magnesium transport in *Salmonella typhimurium*: <sup>28</sup>Mg<sup>2+</sup> transport by the CorA, MgtA, and MgtB systems. *J Bacteriol* **171**(9):4761-6.
- Snively, M. D., J. B. Florer, C. G. Miller und M. E. Maguire.** 1989b. Magnesium transport in *Salmonella typhimurium*: expression of cloned genes for three distinct Mg<sup>2+</sup> transport systems. *J Bacteriol* **171**(9):4752-60.
- Snively, M. D., S. A. Gravina, T. T. Cheung, C. G. Miller und M. E. Maguire.** 1991. Magnesium transport in *Salmonella typhimurium*. Regulation of *mgtA* and *mgtB* expression. *J Biol Chem* **266**(2):824-9.
- Sofia, H. J., V. Burland, D. L. Daniels, G. Plunkett, 3rd und F. R. Blattner.** 1994. Analysis of the *Escherichia coli* genome. V. DNA sequence of the region from 76.0 to 81.5 minutes. *Nucleic Acids Res* **22**(13):2576-86.
- Solioz, M. und C. Vulpe.** 1996. CPx-type ATPases: a class of P-type ATPases that pump heavy metals. *Trends Biochem Sci* **21**(7):237-41.
- Sonnhammer, E. L., S. R. Eddy, E. Birney, A. Bateman und R. Durbin.** 1998. Pfam: multiple sequence alignments and HMM-profiles of protein domains. *Nucleic Acids Res* **26**(1):320-2.
- Southern, E.** 1975. Detection of specific sequences among DNA fragments separated by gel electrophoresis. *J Mol Biol* **98**(3):503-17.
- Spada, S., J. T. Pembroke und J. G. Wall.** 2002. Isolation of a novel *Thermus thermophilus* metal efflux protein that improves *Escherichia coli* growth under stress conditions. *Extremophiles* **6**(4):301-8.
- Sturr, M. G., A. J. Ablooglu und T. A. Krulwich.** 1997. A *Bacillus subtilis* locus encoding several gene products affecting transport of cations. *Gene* **188**(1):91-4.
- Taghavi, S., M. Mergeay und D. van der Lelie.** 1997. Genetic and physical maps of the *Alcaligenes eutrophus* CH34 megaplasmid pMOL28 and its derivative pMOL50 obtained after temperature-induced mutagenesis and mortality. *Plasmid* **37**(1):22-34.

- Tao, T., P. F. Grulich, L. M. Kucharski, R. L. Smith und M. E. Maguire.** 1998. Magnesium transport in *Salmonella typhimurium*: biphasic magnesium and time dependence of the transcription of the *mgtA* and *mgtCB* loci. *Microbiology* **144** (3):655-64.
- Tao, T., M. D. Snavely, S. G. Farr und M. E. Maguire.** 1995. Magnesium transport in *Salmonella typhimurium*: *mgtA* encodes a P-type ATPase and is regulated by  $Mg^{2+}$  in a manner similar to that of the *mgtB* P-type ATPase. *J Bacteriol* **177**(10):2654-62.
- Tartof, K. D. und C. A. Hobbs.** 1987. Improved media for growing plasmid and cosmid clones. *Bethesda Res. Lab. Focus* **9**:2.
- Thanabalu, T., C. Koronakis, C. Hughes und V. Koronakis.** 1998. Substrate-induced assembly of a contiguous channel for protein export from *E. coli*: reversible bridging of an inner-membrane translocase to an outer membrane exit pore. *Embo J* **17**(22):6487-6496.
- Thelwell, C., N. J. Robinson, und J. S. Turner-Cavet.** 1998. An SmtB-like repressor from *Synechocystis* PCC 6803 regulates a zinc exporter. *Proc Natl Acad Sci U S A* **95**(18):10728-33.
- Tibazarwa, C., S. Wuertz, M. Mergeay, L. Wyns und D. van Der Lelie.** 2000. Regulation of the *cnr* cobalt and nickel resistance determinant of *Ralstonia eutropha* (*Alcaligenes eutrophus*) CH34. *J Bacteriol* **182**(5):1399-409.
- Tikhonova, E. B., Q. Wang und H. I. Zgurskaya.** 2002. Chimeric analysis of the multicomponent multidrug efflux transporters from gram-negative bacteria. *J Bacteriol* **184**(23):6499-507.
- Tong, L., S. Nakashima, M. Shibasaka, M. Katsuhara und K. Kasamo.** 2002. A novel histidine-rich CPx-ATPase from the filamentous cyanobacterium *Oscillatoria brevis* related to multiple-heavy-metal cotolerance. *J Bacteriol* **184**(18):5027-35.
- Townsend, D. E., A. J. Esenwine, J. George, 3rd, D. Bross, M. E. Maguire und R. L. Smith.** 1995. Cloning of the *mgtE*  $Mg^{2+}$  transporter from *Providencia stuartii* and the distribution of *mgtE* in gram-negative and gram-positive bacteria. *J Bacteriol* **177**(18):5350-4.
- Toyoshima, C., M. Nakasako, H. Nomura und H. Ogawa.** 2000. Crystal structure of the calcium pump of sarcoplasmic reticulum at 2.6 Å resolution. *Nature* **405**(6787):647-55.
- Toyoshima, C. und H. Nomura.** 2002. Structural changes in the calcium pump accompanying the dissociation of calcium. *Nature* **418**(6898):605-11.
- Tsai, K. J., Y. F. Lin, M. D. Wong, H. H. Yang, H. L. Fu und B. P. Rosen.** 2002. Membrane topology of the p1258 CadA Cd(II)/Pb(II)/Zn(II)-translocating P-type ATPase. *J Bioenerg Biomembr* **34**(3):147-56.
- Tsai, K. J., K. P. Yoon und A. R. Lynn.** 1992. ATP-dependent cadmium transport by the *cadA* cadmium resistance determinant in everted membrane vesicles of *Bacillus subtilis*. *J Bacteriol* **174**(1):116-21.
- Tseng, T. T., K. S. Gratwick, J. Kollman, D. Park, D. H. Nies, A. Goffeau und M. H. Saier, Jr.** 1999. The RND permease superfamily: an ancient, ubiquitous and diverse family that includes human disease and development proteins. *J Mol Microbiol Biotechnol* **1**(1):107-25.

- Tsivkovskii, R., J. F. Eisses, J. H. Kaplan und S. Lutsenko.** 2002. Functional properties of the copper-transporting ATPase ATP7B (the Wilson's disease protein) expressed in insect cells. *J Biol Chem* **277**(2):976-83.
- Turner, J. S., A. P. Morby, B. A. Whitton, A. Gupta und N. J. Robinson.** 1993. Construction of Zn<sup>2+</sup>/Cd<sup>2+</sup> hypersensitive cyanobacterial mutants lacking a functional metallothionein locus. *J Biol Chem* **268**(6):4494-8.
- Ullmann, A.** 1984. One-step purification of hybrid proteins which have beta-galactosidase activity. *Gene* **29**(1-2):27-31.
- Vallee, B. L. und D. S. Auld.** 1990. Zinc coordination, function, and structure of zinc enzymes and other proteins. *Biochemistry* **29**(24):5647-59.
- van der Lelie, D., T. Schwuchow, U. Schwidetzky, S. Wuertz, W. Baeyens, M. Mergeay und D. H. Nies.** 1997. Two-component regulatory system involved in transcriptional control of heavy-metal homeostasis in *Alcaligenes eutrophus*. *Mol Microbiol* **23**(3):493-503.
- van Veen, H. W., T. Abee, G. J. Kortstee, W. N. Konings und A. J. Zehnder.** 1994. Translocation of metal phosphate via the phosphate inorganic transport system of *Escherichia coli*. *Biochemistry* **33**(7):1766-70.
- Vulpe, C., B. Levinson, S. Whitney, S. Packman und J. Gitschier.** 1993. Isolation of a candidate gene for Menkes disease and evidence that it encodes a copper-transporting ATPase. *Nat Genet* **3**(1):7-13.
- Wandersman, C. und P. Delepelaire.** 1990. TolC, an *Escherichia coli* outer membrane protein required for hemolysin secretion. *Proc Natl Acad Sci U S A* **87**(12):4776-80.
- Weast, R. C., M. J. Astle und W. H. Beyer.** 1984. CRC Handbook of chemistry and physics. CRC Press, Florida, USA.
- Weber, K. und M. Osborn.** 1969. The reliability of molecular weight determinations by dodecyl sulfate-polyacrylamide gel electrophoresis. *J Biol Chem* **244**(16):4406-12.
- Williams, L. E., J. K. Pittman und J. L. Hall.** 2000. Emerging mechanisms for heavy metal transport in plants. *Biochim Biophys Acta* **1465**(1-2):104-26.
- Worlock, A. J. und R. L. Smith.** 2002. ZntB is a novel Zn<sup>2+</sup> transporter in *Salmonella enterica* serovar Typhimurium. *J Bacteriol* **184**(16):4369-73.
- Wunderli-Ye, H. und M. Solioz.** 2001. Purification and functional analysis of the copper ATPase CopA of *Enterococcus hirae*. *Biochem Biophys Res Commun* **280**(3):713-9.
- Yanisch-Perron, C., J. Vieira und J. Messing.** 1985. Improved M13 phage cloning vectors and host strains:nucleotide sequence of M13 mp18 and pUC19 vectors. *Gene* **33**(1):103-19.
- Zeng, Q., C. Stalhandske, M. C. Anderson, R. A. Scott und A. O. Summers.** 1998. The core metal-recognition domain of MerR. *Biochemistry* **37**(45):15885-95.
- Zgurskaya, H. I., und H. Nikaido.** 1999. Bypassing the periplasm: reconstitution of the AcrAB multidrug efflux pump of *Escherichia coli*. *Proc Natl Acad Sci U S A* **96**(13):7190-5.
- Zgurskaya, H. I. und H. Nikaido.** 2000a. Cross-linked complex between oligomeric periplasmic lipoprotein AcrA and the inner-membrane-associated multidrug efflux pump AcrB from *Escherichia coli*. *J Bacteriol* **182**(15):4264-7.
- Zgurskaya, H. I. und H. Nikaido.** 2000b. Multidrug resistance mechanisms: drug efflux across two membranes. *Mol Microbiol* **37**(2):219-25.