

University of Groningen

## Structural changes that accompany the self-assembly of hydrophobins

Vocht, Marcel Leo de

**IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.**

*Document Version*

Publisher's PDF, also known as Version of record

*Publication date:*

2001

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Vocht, M. L. D. (2001). *Structural changes that accompany the self-assembly of hydrophobins*. s.n.

### Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

### Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

## References

1. JM Andreu, MJ Gorbunoff, JC Lee, and SN Timasheff (1984) Interaction of tubulin with bifunctional colchicine analogues: an equilibrium study. *Biochemistry* 23, 1742-52.
2. SA Asgeirsdóttir (1994) Proteins involved in the emergent growth of *Schizophyllum commune*. PhD Thesis, University of Groningen, Groningen.
3. SA Asgeirsdóttir, OMH de Vries, and JGH Wessels (1998) Identification of three differentially expressed hydrophobins in *Pleurotus ostreatus* (oyster mushroom). *Microbiology* 144 (Pt 11), 2961-9.
4. SA Asgeirsdóttir, JR Halsall, and LA Casselton (1997) Expression of two closely linked hydrophobin genes of *Coprinus cinereus* is monokaryon-specific and down-regulated by the *oid-1* mutation. *Fungal Genet Biol* 22, 54-63.
5. TT Ashburn, H Han, BF McGuinness, and PTJ Lansbury (1996) Amyloid probes based on Congo Red distinguish between fibrils comprising different peptides. *Chem Biol* 3, 351-8.
6. AM Baty, PA Suci, BJ Tyler, and GG Geesey (1996) Investigation of Mussel Adhesive Protein Adsorption on Polystyrene and Poly(octadecyl methacrylate) Using Angle Dependent XPS, ATR-FTIR, and AFM. *J Colloid Interface Sci* 177, 307-15.
7. HH Bauer, U Aebi, M Haner, R Hermann, M Muller, T Arvinte, and HP Merkle (1995) Architecture and polymorphism of fibrillar supramolecular assemblies produced by *in vitro* aggregation of human calcitonin. *J Struct Biol* 115, 1-15.
8. D Bell-Pedersen, JC Dunlap, and JJ Loros (1992) The *Neurospora* circadian clock-controlled gene, *ccg-2*, is allelic to *eas* and encodes a fungal hydrophobin required for formation of the conidial rodlet layer. *Genes Dev* 6, 2382-94.
9. SF Betz (1993) Disulfide bonds and the stability of globular proteins. *Protein Sci* 2, 1551-8.
10. R Bohlmann (1996) *Isolierung und Charakterisierung von Filamentspezifisch Exprimierten Genen*, University of Munich
11. M Boncheva, and H Vogel (1997) Formation of stable polypeptide monolayers at interfaces: controlling molecular conformation and orientation. *Biophys J* 73, 1056-72.
12. DR Booth, M Sunde, V Bellotti, CV Robinson, WL Hutchinson, PE Fraser, PN Hawkins, CM Dobson, SE Radford, CC Blake, and MB Pepys (1997) Instability, unfolding and aggregation of human lysozyme variants underlying amyloid fibrillogenesis. *Nature* 385, 787-93.
13. CG Bowden, WE Hintz, R Jeng, M Hubbes, and PA Horgen (1994) Isolation and characterization of the *cerato-ulmin toxin* gene of the Dutch elm disease pathogen, *Ophiostoma ulmi*. *Curr Genet* 25, 323-9.
14. JL Brash, and TA Horbett (1995) in *Protein at interfaces II. Fundamentals and applications* (TA Horbett, and JL Brash, eds) Vol. 602 pp. 1-23, American chemical society, Washington.
15. A Brisson, W Bergsma-Schutter, F Oling, O Lambert, and I Reviakine (1999) Two-dimensional crystallization of proteins on lipid monolayers at the air-water interface and transfer to an electron microscopy grid. *J Cryst Growth* 196, 456-70.
16. CE Carpenter, RJ Mueller, P Kazmierczak, L Zhang, DK Villalon, and NK van Alfen (1992) Effect of a virus on accumulation of a tissue-specific cell-surface protein of the fungus *Cryphonectria (Endothia) parasitica*. *Mol Plant-Microbe Interact* 4, 55-61.

17. G Chakrabarti, S Kim, MLJ Gupta, JS Barton, and RH Himes (1999) Stabilization of tubulin by deuterium oxide. *Biochemistry* 38, 3067-72.
18. TC Chang, C-SC Wu, and JT Yang (1978) Circular Dichroic Analysis of Protein Conformation: Inclusion of the  $\beta$ -Turns. *Anal Biochem* 91, 13-31.
19. F Chiti, N Taddei, M Bucciantini, P White, G Ramponi, and CM Dobson (2000) Mutational analysis of the propensity for amyloid formation by a globular protein. *EMBO J* 19, 1441-9.
20. F Chiti, P Webster, N Taddei, A Clark, M Stefani, G Ramponi, and CM Dobson (1999) Designing conditions for in vitro formation of amyloid protofilaments and fibrils. *Proc Natl Acad Sci USA* 96, 3590-4.
21. KA Conway, JD Harper, and PT Lansbury (1998) Accelerated *in vitro* fibril formation by a mutant  $\alpha$ -synuclein linked to early-onset Parkinson disease. *Nature Med* 11, 1318-20.
22. I Cornut, B Desbat, JM Turlet, and J Dufourcq (1996) In situ study by polarization modulated Fourier transform infrared spectroscopy of the structure and orientation of lipids and amphipathic peptides at the air-water interface. *Biophys J* 70, 305-12.
23. F Corpet (1988) Multiple sequence alignment with hierarchical clustering. *Nucl Acid Res* 16, 10881-90.
24. PW De Groot, RT Roeven, LJ Van Griensven, J Visser, and PJ Schaap (1999) Different temporal and spatial expression of two hydrophobin-encoding genes of the edible mushroom *Agaricus bisporus*. *Microbiology* 145, 1105-13.
25. PW De Groot, PJ Schaap, AS Sonnenberg, J Visser, and LJ Van Griensven (1996) The *Agaricus bisporus* hypA gene encodes a hydrophobin and specifically accumulates in peel tissue of mushroom caps during fruit body development. *J Mol Biol* 257, 1008-18.
26. ML de Vocht, I Reviakine, HAB Wösten, A Brisson, JGH Wessels, and GT Robillard (2000) Structural and functional role of the disulfide bridges in the hydrophobin SC3. *J Biol Chem* 275, 28428-32.
27. ML de Vocht, K Scholtmeijer, EW van der Vegte, OMH de Vries, N Sonveaux, HAB Wösten, JM Ruyschaert, G Hadziioannou, JGH Wessels, and GT Robillard (1998) Structural characterization of the hydrophobin SC3, as a monomer and after self-assembly at hydrophobic/hydrophilic interfaces. *Biophys J* 74, 2059-68.
28. OMH de Vries, MP Fekkes, HAB Wösten, and JGH Wessels (1993) Insoluble hydrophobin complexes in the walls of *Schizophyllum commune* and other filamentous fungi. *Arch Microbiol* 159, 330-5.
29. OMH de Vries, S Moore, C Arntz, JGH Wessels, and P Tudzynski (1999) Identification and characterization of a tri-partite hydrophobin from *Claviceps fusiformis*. A novel type of class II hydrophobin. *European Journal Of Biochemistry* 262, 377-85.
30. CM Dobson (1999) Protein misfolding, evolution and disease. *Trends Biochem Sci* 24, 329-33.
31. YF Dufrière, CJP Boonaert, PA Gerin, M Asther, and PG Rouxhet (1999) Direct probing of the surface ultrastructure and molecular interactions of the dormant and germinating spores of *Phanerochate chrysosporium*. *J Bacteriol* 181, 5350-4.
32. ASB Edge, CR Faltynek, L Hof, LEJ Reichert, and P Weber (1981) Deglycosylation of Glycoproteins by Trifluoromethanesulfonic acid. *Anal Biochem* 118, 131-7.
33. NJ Fairbairn (1953) A modified anthrone reagent. *Chemistry and Industry* 4, 86.

34. CD Frisbie, LF Roznyai, A Noy, MS Wrighton, and CM Lieber (1994) Functional Group Imaging by Chemical Force Microscopy. *Science* 265, 2071-3.
35. E Goormaghtigh, V Cabiaux, and J-M Ruyschaert (1990) Secondary structure and dosage of soluble and membrane proteins by attenuated total reflection Fourier-transform infrared spectroscopy on hydrated films. *Eur J Biochem* 193, 409-20.
36. E Goormaghtigh, V Cabiaux, and JM Ruyschaert (1994) Determination of soluble and membrane protein structure by Fourier transform infrared spectroscopy. *Subcell Biochem* 23, 329-450.
37. J-BD Green, MT McDermott, and MD Porter (1995) Nanometer-Scale Mapping of Chemically Distinct Domains at Well-defined Organic Interfaces Using Frictional Force Microscopy. *J Phys Chem* 99, 10960-5.
38. JI Guijarro, M Sunde, JA Jones, ID Campbell, and CM Dobson (1998) Amyloid fibril formation by an SH3 domain. *Proc Natl Acad Sci U S A* 95, 4224-8.
39. AP Gunning, PWJ de Groot, J Visser, and VJ Morris (1998) Atomic force microscopy of a hydrophobin protein from the edible mushroom *Agaricus bisporus*. *J Coll Interface Sci* 201, 118-26.
40. JE Hansen, O Lund, K Rapacki, and S Brunak (1997) O-glycbase version 2.0 - A revised database of O-glycosylated proteins. *Nucleic acids research* 25, 278-82.
41. JE Hansen, O Lund, N Tolstrup, AA Gooley, KL Williams, and S Brunak (1998) Prediction of mucin O-glycosylation sites based on sequence context and surface accessibility. *Glycoconj J* 15, 115-30.
42. JD Harper, and PT Lansbury, Jr. (1997) Models of amyloid seeding in Alzheimer's disease and scrapie: mechanistic truths and physiological consequences of the time-dependent solubility of amyloid proteins. *Annu Rev Biochem* 66, 385-407.
43. CA Haynes, and W Norde (1995) Structures and stabilities of adsorbed proteins. *J Colloid Interface Sci* 169, 313-28.
44. M Hollecker (1989) in *Protein Structure* (TE Creighton, ed) pp. 145-53, IRL Press, Oxford.
45. H Inouye, and DA Kirschner (2000) A $\beta$  fibrillogenesis: kinetic parameters for fibril formation from Congo Red binding. *J Struct Biol* 130, 123-9.
46. JT Jarrett, and PTJ Lansbury (1993) Seeding one-dimensional crystallization of amyloid: a pathogenic mechanism in Alzheimer's disease and scrapie? *Cell* 73, 1055-8.
47. K Jenny, O Käppeli, and A Fiechter (1991) Biosurfactants from *Bacillus licheniformis*: structural analysis and characterization. *Appl Microbiol Biotechnol* 36, 5-13.
48. JL Jiménez, JI Guijarro, E Orlova, J Zurdo, CM Dobson, M Sunde, and HR Saibil (1999) Cryo-electron microscopy structure of an SH3 amyloid fibril and model of the molecular packing. *EMBO J* 18, 815-21.
49. Y Kallberg, M Gustafsson, B Persson, J Thyberg, and J Johansson (2000) Prediction of amyloid-forming proteins. *J Biol Chem* Papers in press. Published December 27, 10.1074/jbc.M010402200.
50. JP Kamerling, and JFG Vliegthart (1989) in *Clinical Biochemistry: Principles, Methods, Applications* (AM Lawson, ed) Vol. I pp. 175-263, Walter de Gruyter, Berlin.
51. JW Kelly (1998) The alternative conformations of amyloidogenic proteins and their multi-step assembly pathways. *Curr Opin Struct Biol* 8, 101-6.

52. MJ Kershaw, G Wakley, and NJ Talbot (1998) Complementation of the mpg1 mutant phenotype in *Magnaporthe grisea* reveals functional relationships between fungal hydrophobins. *EMBO J* 17, 3838-49.
53. DA Kirschner, DB Teplov, and AM Damas (2000) Twist and sheet: variations on the theme of amyloid. *J Struct Biol* 130, 87.
54. WE Klunk, RF Jacob, and RP Mason (1999) Quantifying amyloid beta-peptide (Abeta) aggregation using the Congo red-Abeta (CR-abeta) spectrophotometric assay. *Anal Biochem* 266, 66-76.
55. WE Klunk, JW Pettegrew, and DJ Abraham (1989) Quantitative evaluation of Congo Red binding to amyloid-like proteins with a beta-pleated sheet conformation. *J Histochem Cytochem* 37, 1273-81.
56. A Kondo, F Murakami, and K Higashitani (1992) Circular Dichroism Studies on Conformational Changes in Protein Molecules upon Adsorption on Ultrafine Polystyrene Particles. *Biotech and bioengin* 40, 889-94.
57. T Kowalewski, and DM Holtzman (1999) In situ atomic force microscopy study of Alzheimer's beta-amyloid peptide on different substrates: new insights into mechanism of beta-sheet formation. *Proc Natl Acad Sci USA* 96, 3688-93.
58. GC Kresheck, H Schneider, and Scheraga (1965) *J Phys Chem* 69, 3132-44.
59. A Kumar, and GM Whitesides (1993) Features of gold having micrometer to centimeter dimensions can be formed through a combination of stamping with an elastomeric stamp and an alkanethiol "ink" followed by chemical etching. *Appl Phys Lett* 63, 2002-4.
60. PT Lansbury, Jr. (1999) Evolution of amyloid: what normal protein folding may tell us about fibrillogenesis and disease. *Proc Natl Acad Sci U S A* 96, 3342-44.
61. LM Larraya, P G., MM Penas, JJ Baars, TS Mikosch, AG Pisabarro, and L Ramírez (1999) Molecular karyotype of the white rot fungus *Pleurotus ostreatus*. *Appl Environ Microbiol* 65, 3413-7.
62. FR Lauter, VE Russo, and C Yanofsky (1992) Developmental and light regulation of eas, the structural gene for the rodlet protein of *Neurospora*. *Genes Dev* 6, 2373-81.
63. SH Lee, and E Ruckenstein (1988) Adsorption of Proteins onto Polymeric Surfaces of Different Hydrophobicities-A Case Study with Bovine Serum Albumin. *J Colloid Interface Sci* 125, 365-79.
64. HD LeVine (1993) Thioflavine T interaction with synthetic Alzheimer's disease beta-amyloid peptides: detection of amyloid aggregation in solution. *Protein Sci* 2, 404-10.
65. L Li, TA Darden, L Bartolotti, D Kominos, and LG Pedersen (1999) An atomic model for the pleated beta-sheet structure of Abeta amyloid protofilaments. *Biophys J* 76, 2871-8.
66. GP López, HA Biebuyck, and GM Whitesides (1993) Scanning electron microscopy can form images of patterns in self-assembled monolayers. *Langmuir* 9, 1513-6.
67. JM Lora, J de la Cruz, T Benitez, A Llobell, and JA Pintor-Toro (1994) A putative catabolite-repressed cell wall protein from the mycoparasitic fungus *Trichoderma harzianum*. *Mol Gen Genet* 242, 461-6.
68. LG Lugones, JS Bosscher, K Scholtmeijer, OM de Vries, and JG Wessels (1996) An abundant hydrophobin (ABH1) forms hydrophobic rodlet layers in *Agaricus bisporus* fruiting bodies. *Microbiology* 142, 1321-9.

69. LG Lugones, K Scholtmeijer, R Klootwijk, and JG Wessels (1999) Introns are necessary for mRNA accumulation in *Schizophyllum commune*. *Mol Microbiol* 32, 681-9.
70. LG Lugones, HAB Wösten, KU Birkenkamp, KA Sjollema, J Zagers, and JGH Wessels (1999) Hydrophobins line air channels in fruiting bodies of *Schizophyllum commune* and *Agaricus bisporus*. *Mycol Res* 103, 635-40.
71. LG Lugones, HAB Wösten, and JGH Wessels (1998) A hydrophobin (ABH3) specifically secreted by vegetatively growing hyphae of *Agaricus bisporus* (common white button mushroom). *Microbiology* 144, 2345-53.
72. D Marsh (1997) Dichroic ratios in polarized fourier transform infrared for nonaxial symmetry of  $\beta$ -sheet structures. *Biophys J* 72, 2710-8.
73. MCL Maste, EHW Pap, A van Hoek, W Norde, and AJWG Visser (1996) Spectroscopic Investigation of the Structure of a Protein Adsorbed on a Hydrophobic Latex. *J Colloid Interface Sci* 180, 632-3.
74. DJ Müller, M Amrein, and A Engel (1997) Adsorption of biological molecules to a solid support for scanning probe microscopy. *J Struct Biol* 119, 172-88.
75. G Muñoz, T Nakari-Setälä, E Agosin, and M Penttilä (1997) Hydrophobin gene *srh1*, expressed during sporulation of the biocontrol agent *Trichoderma harzianum*. *Curr Genet* 32, 225-30.
76. T Nakari-Setälä, N Aro, M Ilmén, G Muñoz, N Kalkkinen, and M Penttilä (1997) Differential expression of the vegetative and spore-bound hydrophobins of *Trichoderma reesei*-cloning and characterization of the *hfb2* gene. *European Journal Of Biochemistry* 248, 415-23.
77. T Nakari-Setälä, N Aro, N Kalkkinen, E Alatalo, and M Penttilä (1996) Genetic and biochemical characterization of the *Trichoderma reesei* hydrophobin HFBI. *Eur J Biochem* 235, 248-55.
78. WL Ng, TP Ng, and HS Kwan (2000) Cloning and characterization of two hydrophobin genes differentially expressed during fruit body development in *lentinula edodes*. *FEMS Microbiol Lett* 185, 139-45.
79. J Noordmans, and HJ Busscher (1991) The influence of droplet volume and contact angle on liquid surface tension measurements by axisymmetric drop shape analysis-profile (ADSA-P). *Colloids Surf* 58, 239-249.
80. W Norde (1996) Driving forces for protein adsorption at solid surfaces. *Macromol Symp* 103, 5-18.
81. A Noy, CD Frisbie, LF Roznyai, MS Wrighton, and CM Lieber (1995) Chemical force microscopy: exploiting chemically-modified tips to quantify adhesion, friction, and functional group distribution in molecular assemblies. *J Am Chem Soc* 117, 7943-51.
82. TG Oas, and EJ Toone (1997) Thermodynamic solvent isotope effects and molecular hydrophobicity. *Adv Biophys Chem* 6, 1-52.
83. F Oosawa, and S Asakura (1975) Thermodynamics of the polymerization of protein, Academic Press, London.
84. M Parta, Y Chang, S Rulong, P Pinto-DaSilva, and KJ Kwon-Chung (1994) *HYP1*, a hydrophobin gene from *Aspergillus fumigatus*, complements the rodletless phenotype in *Aspergillus nidulans*. *Infect Immun* 62, 4389-95.

85. MM Peñas, SA Asgeirsdóttir, I Lasa, FA Culiñez-Macià, AG Pisabarro, JGH Wessels, and L Ramírez (1998) Identification, characterization, and In situ detection of a fruit-body-specific hydrophobin of *Pleurotus ostreatus*. *Appl Environ Microbiol* 64, 4028-34.
86. H Puchtler, F Sweat, and M Levine (1962) On the binding of Congo red by amyloid. *J Histochem* 10, 355-64.
87. M Ramirez-Alvarado, JS Merkel, and L Regan (2000) A systematic exploration of the influence of protein stability on amyloid formation *in vitro*. *Proc Natl Acad Sci USA* 97, 8979-84.
88. WC Richards (1993) in *Dutch Elm Research: Cellular and Molecular Approaches* (MB Sticklen, and JL Sberald, eds) pp. 89-151, Springer Verlag, New York.
89. WC Richards, and S Takai (1973) Novel technique for isolating microstructures present in shaken cultures of the fungus *Ceratocystis ulmi*. *Appl Microbiol* 26, 443-4.
90. B Rost, and C Sander (1993) Prediction of protein structure at better than 70% accuracy. *J Mol Biol* 232, 584-99.
91. B Rost, and C Sander (1994) Combining evolutionary information and neural networks to predict protein secondary structure. *Proteins* 19, 55-72.
92. B Rost, C Sander, and R Schneider (1994) PHD - an automatic mail server for protein secondary structure prediction. *CABIOS* 10, 53-60.
93. PS Russo, FD Blum, JD Ipsen, WG Miller, and YJ Abul-Hajj (1982) The surface activity of the phytotoxin cerato-ulmin. *Can J Bot* 60, 1414-22.
94. C Santos, and J Labarere (1999) *Aa-Pri2*, a single-copy gene from *Agrocybe aegerita*, specifically expressed during fruiting initiation, encodes a hydrophobin with a leucine-zipper domain. *Curr Genet* 35, 564-70.
95. S Scherrer, OMH de Vries, R Dudler, JGH Wessels, and R Honegger (2000) Interfacial self-assembly of fungal hydrophobins of the lichen forming ascomycetes *Xanthoria parietina* and *X. etaneoides*. *Fungal Genet Biol* 30, 81-93.
96. C Schladitz, EP Euridice, H Hermel, and H Möhwald (1999) Amyloid- $\beta$ -sheet formation at the air-water interface. *Biophys J* 77, 3305-10.
97. K Scholtmeijer, B Gerssen, ML de Vocht, B van Leeuwen, HAB Wösten, and JGH Wessels (2000) in *Expression and engineering of hydrophobin genes*, PhD Thesis, University of Groningen, Groningen.
98. FHJ Schuren, and JGH Wessels (1990) Two genes specifically expressed in fruiting dikaryons of *Schizophyllum commune*. homologues with a gene not regulated by mating-type genes. *Gene* 90, 199-205.
99. R Schuster (1988) Determination of amino acids in biological, pharmaceutical, plant and food samples by automated precolumn derivatization and high-performance liquid chromatography. *J Chromatogr* 431, 271-84.
100. GC Segers, W Hamada, RP Oliver, and PD Spanu (1999) Isolation and characterisation of five different hydrophobin-encoding cDNAs from the fungal tomato pathogen *Cladosporium fulvum*. *Mol Gen Genet* 261, 644-52.
101. LC Serpell, M Sunde, PE Fraser, PK Luther, EP Morris, O Sangren, E Lundgren, and CCF Blake (1995) Examination of the structure of the transthyretin amyloid fibril by image reconstruction from electron micrographs. *J Mol Biol* 254, 113-8.

102. FS Sjöstrand, and J Rhodin (1957) Electron microscopy : proceedings of the Stockholm conference, Almqvist & Wiksell, Stockholm.
103. P Spanu (1997) HCF-1, a hydrophobin from the tomato pathogen *Cladosporium fulvum*. *Gene* 193, 89-96.
104. RJ St. Leger, RC Staples, and DW Roberts (1992) Cloning and regulatory analysis of starvation-stress gene, *ssgA*, encoding a hydrophobin-like protein from the entomopathogenic fungus, *Metarhizium anisopliae*. *Gene* 120, 119-24.
105. MA Stringer, RA Dean, TC Sewall, and WE Timberlake (1991) Rodletness, a new *Aspergillus* developmental mutant induced by directed gene inactivation. *Genes Dev* 5, 1161-71.
106. MA Stringer, and WE Timberlake (1995) *devA* encodes a fungal hydrophobin component of the *Aspergillus* spore wall. *Mol Microbiol* 16, 33-44.
107. M Sunde, LC Serpell, M Bartlam, PE Fraser, MB Pepys, and CC Blake (1997) Common core structure of amyloid fibrils by synchrotron X-ray diffraction. *J Mol Biol* 273, 729-39.
108. D Tagu, B Nasse, and F Martin (1996) Cloning and characterization of hydrophobins-encoding cDNAs from the ectomycorrhizal basidiomycete *Pisolithus tinctorius*. *Gene* 168, 93-7.
109. S Takai, and WC Richards (1978) Cerato-ulmin, a wilting toxin of *Ceratocystis ulmi*: isolation and some properties of cerato-ulmin from the culture of *C. ulmi*. *Phytopathol Z* 91, 129-46.
110. NJ Talbot, DJ Ebbole, and JE Hamer (1993) Identification and characterization of *MPG1*, a gene involved in pathogenicity from the rice blast fungus *Magnaporthe grisea*. *Plant Cell* 5, 1575-90.
111. NJ Talbot, M Kershaw, GE Wakley, OMH de Vries, JGH Wessels, and JE Hamer (1996) *MPG1* encodes a fungal hydrophobin involved in surface interactions during infection-related development of the rice blast fungus *Magnaporthe grisea*. *Plant Cell* 8, 985-999.
112. G Taubes (1996) Misfolding the way to disease. *Science* 271, 1493-5.
113. N Thau, M Monod, B Crestani, C Rolland, G Tronchin, JP Latgé, and S Paris (1994) Rodletless mutants of *Aspergillus fumigatus*. *Infect Immun* 62, 4380-8.
114. RC Thomas, JE Houston, RM Crooks, T Kim, and TA Michalske (1995) Probing adhesion forces at the molecular scale. *J Am Chem Soc* 117, 3830-4.
115. EB Thoughton, CD Bain, GM Whitesides, RG Nuzzo, DL Alara, and MD Porter (1988) Monolayer films prepared by the spontaneous self-assembly of symmetrical and unisymmetrical dialkyl sulfides from solution onto gold substrates: structure, properties, and reactivity of constituent functional groups. *Langmuir* 4, 465-85.
116. SG Timasheff (1981) in *Protein-protein interactions* pp. 315-36, Wiley, New York.
117. SN Timasheff, and LM Grisham (1980) In vitro assembly of cytoplasmic microtubules. *Annu Rev Biochem* 49, 565-91.
118. LO Tjenberg, DJE Callaway, A Tjenberg, S Hahne, C Lilliehöök, L Terenius, J Thyberg, and C Nordstedt (1999) A molecular model of Alzheimer amyloid  $\beta$ -peptide fibril formation. *J Biol Chem* 274, 12619-25.
119. C Tribet, R Audebert, and J-L Popot (1996) Amphipols: Polymers that keep membrane proteins soluble in aqueous solutions. *Proc Natl Acad Sci USA* 93, 15047-50.
120. WP Ulrich, and H Vogel (1999) Polarization-modulated FTIR spectroscopy of lipid/gramicidin monolayers at the air/water interface. *Biophys J* 76, 1639-47.



121. HC van der Mei, M Rosenberg, and HJ Busscher (1991) in *Microbial cell surface analysis* pp. 261-87, VCH Publishers, New York.
122. W van der Vegt, HC van der Mei, HA Wösten, JG Wessels, and HJ Busscher (1996) A comparison of the surface activity of the fungal hydrophobin SC3p with those of other proteins. *Biophys Chem* 57, 253-60.
123. EW van der Vegt, and G Hadziioannou (1997) Scanning force microscopy with chemical specificity: an extensive study of chemically specific tip-surface interactions and the chemical imaging of surface functional groups. *Langmuir* 13, 4357-68.
124. M-A van Wetter, FHJ Schuren, TA Schuurs, and JGH Wessels (1996) Targeted mutation of the SC3 hydrophobin gene of *Schizophyllum Commune* affects formation of aerial hyphae. *FEMS Microbiol Lett* 140, 265-9.
125. M-A van Wetter, HAB Wösten, JH Sietsma, and JGH Wessels (2000) Hydrophobin gene expression affects hyphal wall composition in *Schizophyllum commune*. *Fungal genet biol* 0, 1-6.
126. M-A Van Wetter, HAB Wösten, and JGH Wessels (2000) SC3 and SC4 hydrophobins have distinct roles in formation of aerial structures in dikaryons of *Schizophyllum commune*. *Mol Microbiol* 36, 201-10.
127. JGH Wessels (1993) Cell wall growth, protein excretion and morphogenesis in fungi. *Transley Review No 45 New Phytol* 123, 397-413.
128. JGH Wessels (1994) Developmental regulation of fungal cell wall formation. *Ann Rev Phytopathol* 32, 413-37.
129. JGH Wessels (1996) Fungal hydrophobins, protein that function at an interface. *Trends Plant Sc* 1, 9-15.
130. JGH Wessels (1997) Hydrophobins: proteins that change the nature of the fungal surface. *Adv Microb Physiol* 38, 1-45.
131. JGH Wessels (1999) Fungi in their own right. *Fungal Genet Biol* 27, 134-145.
132. JGH Wessels, SA Ásgeirsdóttir, KU Birkenkamp, OMH de Vries, LG Lugones, JMJ Scheer, FHJ Schuren, TA Schuurs, M-A van Wetter, and HAB Wösten (1995) Genetic Regulation of emergent growth in *Schizophyllum commune*. *Can J Bot* 73, S273-S281.
133. JGH Wessels, OMH de Vries, SA Asgeirsdóttir, and FHJ Schuren (1991) Hydrophobin genes involved in formation of aerial hyphae and fruit bodies in *Schizophyllum commune*. *Plant Cell* 3, 793-9.
134. JGH Wessels, OMH de Vries, SA Asgeirsdóttir, and J Springer (1991) The thn mutation of *Schizophyllum commune*, which suppresses formation of aerial hyphae, affects expression of the Sc3 hydrophobin gene. *J Gen Microbiol* 137, 2439-45.
135. I Willner, and E Katz (2000) Integration of layered redox proteins and conductive supports for bioelectronic applications. *Angew Chem Int Ed* 39, 1180-218.
136. HAB Wösten (2001) Hydrophobins, multiple-purpose proteins. *Annu Rev Microbiol*
137. HAB Wösten, SA Asgeirsdóttir, JH Krook, JH Drenth, and JGH Wessels (1994) The fungal hydrophobin Sc3p self-assembles at the surface of aerial hyphae as a protein membrane constituting the hydrophobic rodlet layer. *Eur J Cell Biol* 63, 122-9.
138. HAB Wösten, and ML de Vocht (2000) Hydrophobins, the fungal coat unravelled. *Biochim Biophys Acta* 1469 (2), 79-86.

139. HAB Wösten, OMH de Vries, HC van der Mei, HJ Busscher, and JGH Wessels (1994) Atomic composition of the hydrophobic and hydrophilic membrane sides of self-assembled SC3p hydrophobin. *J Bacteriol* 176, 7085-6.
140. HAB Wösten, OMH de Vries, and JGH Wessels (1993) Interfacial self-assembly of a fungal hydrophobin into a hydrophobic rodlet layer. *Plant Cell* 5, 1567-74.
141. HAB Wösten, TG Ruardy, HC van der Mei, HJ Busscher, and JGH Wessels (1995) Interfacial self-assembly of a *Schizophyllum commune* hydrophobin into an insoluble amphipathic membrane depends on surface hydrophobicity. *Colloids Surf B: Biointerfaces* 5, 189-95.
142. HAB Wösten, FHJ Schuren, and JGH Wessels (1994) Interfacial self-assembly of a hydrophobin into an amphipathic protein membrane mediates fungal attachment to hydrophobic surfaces. *EMBO J* 13, 5848-54.
143. HAB Wösten, M-A van Wetter, LG Lugones, HC van der Mei, HJ Busscher, and JGH Wessels (1999) How a fungus escapes the water to grow into the air. *Curr Biol* 9, 85-8.
144. HAB Wösten, and JGH Wessels (1997) Hydrophobins, from molecular structure to multiple functions in fungal development. *Mycoscience* 38, 363-374.
145. HAB Wösten, and JM Willey (2000) Surface-active proteins enable microbial aerial hyphae to grow in the air. *Microbiology* 146, 767-73.
146. H Wu, Y Fan, J Seng, and S-F Sui (1993) Induction of changes in the secondary structure of globular protein by a hydrophobic surface. *Eur Biophys J* 22, 201-5.
147. J Wu, and JT Watson (1997) A novel methodology for assignment of disulfide bond pairings in proteins. *Protein Sci* 6, 391-8.
148. M Yaguchi, M Pusztai-Carey, C Roy, WK Surewicz, PR Carey, KJ Stevenson, WC Richards, and S Takai (1993) in *Dutch elm disease research, cellular and molecular approaches* (MD Sticklen, and JL Sherald, eds) pp. 152-70, Springer Verlag, New York.
149. L Zhang, D Villalon, Y Sun, P Kazmierczak, and NK van Alfen (1994) Virus-associated down-regulation of the gene encoding cryparin, an abundant cell-surface protein from the chestnut blight fungus, *Cryphonectria parasitica*. *Gene* 139, 59-64.