

6 Literatur

- Aarts, N., Metz, M., Holub, E., Stascawicz, B. J., Daniels, M. J., Parker, J. E. (1998) Different requirements for *EDS1* and *NDR1* by disease resistance genes define at least two *R* gene-mediated signaling pathways in *Arabidopsis*. Proc. Natl. Acad. Sci. USA 95, 10306-10311.
- Alessi, D. R., Cuenda, A., Cohen, P., Dudley, D., Saltiel, A. R. (1995) PD 098059 is a specific inhibitor of the activation of mitogen-activated protein kinase kinase *in vitro* and *in vivo*. J. Biol. Chem. 270, 27489-27494.
- Allen, J. B., Walberg, M. W., Edwards, M. C., Elledge, S. J. (1995) Finding prospective partners in the library: the two-hybrid system and phage display find a match. Trends Biochem. Sci. 20, 511-516.
- Altschul, S. F., Gish, W., Miller, W., Myers, E. W., Lipman, D. J. (1990) Basic local alignment search tool. J. Mol. Biol. 215, 403-410.
- Altschul, S. F., Madden, T. L., Schäffer, A. A., Zhang, J., Zhang, Z., Miller, W., Lipman, D. J. (1997) Gapped BLAST and PSI-BLAST: a new generation of protein database search programs. Nucl. Acid Res. 25, 3389-3402.
- Alvarez, M. E., Pennell, R. I., Meijer, P. J., Ishakawa, A., Dixon, R. A., Lamb, C. (1998) Reactive oxygen intermediates mediate a systemic network in the establishment of plant immunity. Cell 92, 773-784.
- Arias, J. A., Dixon, R. A., Lamb, C. J. (1992) Dissection of the functional architecture of a plant defense gene promoter using a homologous *in vitro* transcription initiation system. Plant Cell 5, 485-496.
- Bailey, J. A., Mansfield, J. W. (1982) Phytoalexins. John Wiley and Sons, New York.
- Baker, C. J., Orlandi, E. W. (1995) Active oxygen in plant pathogenesis. Ann. Rev. Phytopath. 33, 299-321.
- Bardwell, L., Cook, J. G., Voora, D., Baggott, D. M., Martinez, A. R., Thorner, J. (1998) Repression of yeast Ste12 transcription factor by direct binding of unphosphorylated Kss1 MAPK and its regulation by the Ste7 MEK. Genes Dev. 12, 2887-2898.
- Bardwell, L., Cook, J. G., Voora, D., Chang, E. C., Cairns, B. R., Thorner, J. (1996) Signaling in the yeast pheromone response pathway: specific and high-affinity interaction of the mitogen-activated protein (MAP) kinases Kss1 and Fus3 with the upstream MAP kinase kinase Ste7. Mol. Cell. Biol. 16, 3637-3650.

- Bartel, P. A., Chien, C.-T., Sternglanz, R., Fields, S. (1993a) Using the two-hybrid system to detect protein-protein interactions. In: Cellular interactions and development: A practical approach. (Hartley, D. A., ed.) IRL Press, New York, pp 153-179.
- Bartel, P. A., Chien, C.-T., Sternglanz, R., Fields, S. (1993b) Elimination of false positives that arise in using the two-hybrid system. *Biotechniques* 14, 920-924.
- Bögre, L., Calderini, O., Binarova, P., Mattauch, M., Till, S., Kiegerl, S., Jonak, C., Pollaschek, C., Barker, P., Huskisson, N. S., Hirt, H., Heberle-Bors, E. (1999) A MAP kinase is activated late in plant mitosis and becomes localized to the plane of cell division. *Plant Cell* 11 (1), 101-114.
- Bögre, L., Ligterink, W., Heberle-Bors, E., Hirt, H. (1996) Mechanosensors in plants. *Nature* 383, 489-490.
- Bögre, L., Ligterink, W., Meskine, I., Barker, P. J., Heberle-Bors, E., Huskisson, N. S., Hirt, H. (1997) Wounding induces the rapid and transient activation of a specific MAP kinase pathway. *Plant Cell* 9, 75-83.
- Boller, T. (1995) Chemoperception of microbial signals in plant cells. *Ann. Rev. Plant Physiol. Plant Mol. Biol.* 46, 189-214.
- Bostock, R. M., Kuc, J. A., Laine, R. A. (1981) Eicosapentaenoic and arachidonic acids from *Phytophthora infestans* elicit fungitoxic sesquiterpenes in potato. *Science* 212, 67-69.
- Bowles, D. J. (1990) Defense-related proteins in higher plants. *Ann. Rev. Biochem.* 59, 873-907.
- Bradford, M. (1976) A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal. Biochem.* 72, 248-254.
- Brisson, L. F., Tenhaken, R., Lamb, C. (1994) Function of oxidative cross-linking of cell wall structural proteins in plant disease resistance. *Plant Cell* 6, 1703-1712.
- Brunet, A., Roux, D., Lenormand, P., Dowd, S., Keyse, S., Pouyssegur, J. (1999) Nuclear translocation of p42/p44 mitogen-activated protein kinase is required for growth factor-induced gene expression and cell cycle entry. *EMBO J.* 18 (3), 664-674.
- Brunner, D., Oellers, N., Szabad, J., Biggs, W. H., Zipursky, S. L., Hafen, E. (1994) A gain-of-function mutation in drosophila MAP kinase activates multiple receptor tyrosine kinase signaling pathways. *Cell* 76, 875-888.

- Calderini, O., Bögre, L., Vicente, O., Binarova, P., Heberle-Bors, E., Wilson, C. (1998) A cell cycle-regulated MAP kinase with a possible role in cytokinesis in tobacco cells. *J. Cell Sci.* 11, 3091-3100.
- Camps, M., Nichols, A., Gillieron, C., Antonsson, B., Muda, M., Chabert, C., Boschert, U., Arkinstall, S. (1998) Catalytic activation of the phosphatase MPK-3 by ERK2 mitogen-activated protein kinase. *Science* 280, 1262-1265.
- Canagarajah, B., Khokhlatchev, A. V., Cobb, M. H., Goldsmith, E. (1997) Activation mechanism of the MAP kinase ERK2 by dual phosphorylation. *Cell* 90, 859-869.
- Cano, E., Mahadevan, L. C. (1995) Parallel signal processing among mammalian MAPKs. *Trends Biochem. Sci.* 20, 117-122.
- Cassab, G. I. (1998) Plant cell wall proteins. *Ann. Rev. Plant Physiol. Plant Mol. Biol.* 49, 281-310.
- Century, K. S., Holub, E. B., Stascawicz, B. J. (1995) *NDR 1*, a locus of *Arabidopsis thaliana* that is required for disease resistance to both a bacterial and a fungal pathogen. *Proc. Natl. Acad. Sci. USA* 92, 6597-6601.
- Century, Shapiro, A. D., Repetti, P. P., Dahlbeck, D., K. S., Holub, E. B., Stascawicz, B. J. (1997) *NDRI*, a pathogen-induced component required for Arabidopsis disease resistance. *Science* 278, 1963-1965.
- Chandra, S., Low, P. S. (1997) Measurement of Ca^{2+} fluxes during elicitation of the oxidative burst in aequorin-transformed tobacco cells. *J. Biol. Chem.* 272, 28274-28280.
- Chen, R.-H., Sarnecki, C., Blenis, J. (1992) Nuclear localization of *erk*- and *rsk*-encoded protein kinases. *Mol. Cell. Biol.* 12, 915-927.
- Chien, C.-T., Bartel, P. A., Sternglanz, R., Fields, S. (1991) The two-hybrid system: A method to identify and clone genes for proteins that interact with a protein of interest. *Proc. Natl. Acad. Sci. USA* 88, 9578-9582.
- Clark, S. E., Williams, R. W., Meyrowitz, E. M. (1997) The *CLAVATA1* gene encodes a putative receptor kinase that controls shoot and floral meristem size in arabidopsis. *Cell* 89, 575-585.
- Cobb, M. H. (1999) MAP kinase pathways. *Progr. Biophys. Mol. Biol.* 71, 479-500.
- Cobb, M. H., Goldsmith, E. J. (1995) How MAP kinases are regulated. *J. Biol. Chem.* 270 (25), 14843-14846.
- Conrath, U., Jeblinck, W., Kauss, H. (1991) The protein kinase inhibitor, K252a, decreases elicitor induced Ca^{2+} uptake and K^{+} release, and increases coumarin synthesis in parsley cells. *FEBS Lett.* 279, 141-144.

- Cook, S. J., Beltmann, J., Cadwallader, K. A., MacMahon, M., McCormick, F. (1997) Regulation of MAP kinase phosphatase-1 expression by extracellular signal-related kinase-dependent and Ca²⁺-dependent pathways in rat-1 cells. *J. Biol. Chem.* 272, 13309-13319.
- Cosio, E. G., Frey, T., Verduyn, R., Van Boom, J., Ebel, E. (1990) High affinity binding of a synthetic heptaglycoside and fungal glucan phytoalexin elicitors to soybean membranes. *FEBS Lett.* 175, 309-315.
- Cowley, S., Paterson, H., Kemp, P., Marshall, C. J. (1994) Activation of MAP kinase kinase is sufficient for P12 differentiation and for transformation of NIH 3T3 cells. *Cell* 77, 841-852.
- Cross, A. R., Jones, O. T. G. (1986) The effect of diphenylene iodonium on the superoxide-generating system of neutrophils. *Biochem. J.* 237, 111-116.
- da Costa e Silva, O., Klein, L., Schmelzer, E., Trezzini, G. F., Hahlbrock, K. (1993) BPF-1, a pathogen-induced DNA-binding protein involved in the plant defense response. *Plant J.* 4, 125-135.
- Dangl, J. L., Dietrich, R. A., Richberg, M. H. (1996) Death don't have no mercy: Cell death programs in plant-microbe interactions. *Plant Cell* 8, 1793-1807.
- Dangl, J. L., Hauffe, K. D., Lipphardt, S., Hahlbrock, K., Scheel, D. (1987) Parsley protoplasts retain differential responsiveness to UV light and fungal elicitor. *EMBO J.* 6, 2551-2556.
- De Wit, P. J. G. M. (1997) Pathogen avirulence and plant resistance: A key role for recognition. *Trends Plant Sci.* 2, 452-458.
- Decroocq-Ferrant, V., Decroocq, S., Went, J. V., Schmidt, E., Kreis, M. (1995) A homologue of the MAP/ERK family of protein kinase genes is expressed in vegetative and female reproductive organs of *Petunia hybrida*. *Plant Mol. Biol.* 27, 339-350.
- Dellaporte, S. L., Wood, J., Hicks, J. B. (1983) A plant DNA miniprep: version II. *Plant Mol. Biol. Rep.* 1 (4), 19-21.
- Delledonne, M., Xia, Y., Dixon, R. A., Lamb, C. (1998) Nitric oxide signal functions in plant disease resistance. *Nature* 394, 585-588.
- Després, C., Subramaniam, R., Matton, D. P., Brisson, N. (1995) The activation of the potato *PR-10a* Gene requires the phosphorylation of the nuclear factor PBF-1. *Plant Cell* 7, 589-598.
- Dietrich, A., Mayer, J. E., Hahlbrock, K. (1990) Fungal elicitor triggers rapid, transient, and specific protein phosphorylation in parsley cell suspension cultures. *J. Biol. Chem.* 265, 6360-6368.

- Dixon, R. A., Paiva, N. L. (1995) Stress-induced phenylpropanoid metabolism. *Plant Cell* 7, 1085-97.
- Dong, X. (1998) SA, JA, ethylene, and disease resistance in plants. *Curr. Opin. Plant Biol.* 1, 316-323.
- Dröge-Laser, W., Kaiser, A., Lindsay, W. P., Halkier, B. A., Loake, G. J., Doerner, P., Dixon, R. A., Lamb, C. (1997) Rapid stimulation of a soybean protein-serine kinase that phosphorylates a novel bZIP DNA-binding protein G/HBF-1, during the induction of early transcription factor-dependent defense. *EMBO J.* 16 (4), 726-738.
- Dron, M., Clouse, S. D., Lawton, M. A., Dixon, R. A., Lamb, C. (1988) Glutathione and fungal elicitor regulation of a plant defense gene promoter in electroporated protoplasts. *Proc. Natl. Acad. Sci. USA* 85, 6738-6742.
- Durner, J., Wendehenne, D., Klessig, D. F. (1998). Defense gene induction in tobacco by nitric oxid, cyclic GMP, and cyclic ADP-ribose. *Proc. Natl. Acad. Sci. USA* 95, 10328-10333.
- Ebel, J, Cosio, E. G. (1994) Elicitors of plant defense responses. *Int. Rev. Cytol.* 148, 1-36.
- Ebel, J., Mithöfer, A. (1998) Early events in the elicitation of plant defence. *Planta* 206, 335-348.
- Ebel, J., Scheel, D. (1992) Elicitor recognition and signal transduction. In: *Plant gene research. Genes involved in plant defense* (Boller, T., Meins, F., eds.), Springer Verlag, Berlin, pp. 183-205.
- Ebel, J., Scheel, D. (1997) Signals in host-parasite interaction. In: *The Mycota, Part A, Plant Relationships* (Carroll, G., Tudzynski, P., eds.), Springer Verlag, Berlin, pp. 85-105.
- Falk, A., Feys, B. J., Frost, L. N., Jones, J. D. G., Daniels, M. J., Parker, J. E. (1999) *EDS1*, an essential component of R-gene-mediated disease resistance in *Arabidopsis* has homology to eukaryotic lipases. *Proc. Natl. Acad. Sci. USA* 96, 3292-3297.
- Favata, M. F., Horiuchi, K. Y., Manos, E. J., Daulerio, A. J., Stradley, D. A., Feeser, W. S., Dyk, D. E., Pitts, W. J., Earl, R. A., Hobbs, F., Copeland, R. A., Magolda, R. L., Scherel, P. A., Trzaskos, M. (1998) Identification of a novel inhibitor of mitogen-activated protein kinase kinase. *J. Biol. Chem.* 273 (29), 18623-18632.
- Feldbrügge, M., Sprenger, M., Dinkelbach, M., Yazaki, K., Harter, K., Weisshaar, B. (1994) Functional analysis of a light responsive plant bZIP transcriptional regulator. *Plant Cell.* 6, 1607-1621.

- Felix, G., Grosskopf, D. G., Regenass, M., Boller, T (1991) Rapid changes in protein phosphorylation are involved in transduction of the elicitor signal in plant cells. *Proc. Natl. Acad. Sci. USA* 88, 8831-8834.
- Felix, G., Regenass, M., Boller, T. (1993) Specific perception of subnanomolar concentrations of chitin fragments by tomato cells: induction of extracellular alkalinization, changes in protein phosphorylation, and establishment of a refractory state. *Plant J.* 4, 307-316.
- Felix, G., Regenass, M., Spanu, P., Boller, T. (1994) The protein phosphatase inhibitor calyculin A mimics elicitor action in plant cells and induces rapid hyperphosphorylation of specific proteins as revealed by pulse labeling with [³³P]-phosphate. *Proc. Natl. Acad. Sci. USA* 91, 952-956.
- Feng, Y., Song, L. Y., Kincaid, E., Mahanty, S. K., Elion, E. A. (1998) Functional binding between Gβ and the LIM domain of Ste5 is required to activate the MEKK Ste11. *Curr. Biol.* 8, 267-278.
- Ferrell, J. E. (1996) Tipping the switch fantastic: how a protein kinase cascade can convert graded inputs into switch like outputs. *Trends Biochem. Sci.* 21, 460-466.
- Fields, S., Song, O.-K. (1989) A novel genetic system to detect protein-protein interactions. *Nature* 340, 245-246.
- Flor, H. H. (1971) Current status of gene-for-gene concept. *Annu. Rev. Phytopath.* 9, 275-296.
- Frankhauser, C., Yeh, K.-C., Lagarias, J. C., Zhang, H., Elich, T. D., Chory, J. (1999) PKS1, a substrate phosphorylated by phytochrome that modulates light signaling in arabidopsis. *Science* 284, 1539-1541.
- Fukuda, M., Gotoh, I., Gotoh, Y, Nishida, E. (1996) Cytoplasmic localisation of MAP kinase kinase directed by its NH₂-terminal, leucine-rich short amino acid sequence, which acts as nuclear export signal. *J. Biol. Chem.* 271, 20024-20028.
- Fukuda, M., Gotoh, Y, Nishida, E. (1997) Interaction of MAP kinase with MAP kinase kinase: its possible role in the control of nucleocytoplasmic transport of MAP kinase. *EMBO J.* 16 (8), 1901-1908.
- Fukunaga, R., Hunter, T. (1997) MNK1, a new MAP kinase-activated protein kinase, isolated by a novel expression screening method for identifying protein kinase substrates. *EMBO J.* 16, 1921-1933.
- Gelli, A., Higgins, V. J., Blumwald, E. (1997) Activation of plant plasma membrane Ca²⁺-permeable channels by race-specific fungal elicitors. *Plant Physiol.* 113, 269-279.

- Gietz, R. G., Woods, R. A. (1993) High efficiency transformation with lithium acetate. In: Cellular interactions and development: A practical approach. (Hartley, D. A., ed.), IRL Press, New York, pp. 181-196.
- Glazebrook, J. L., Ausubel, F. M. (1994) Isolation of phytoalexin-deficient mutants of *Arabidopsis thaliana* and characterization of their interaction with bacterial pathogens. *Proc. Natl. Acad. Sci. USA* 91, 8955-8959.
- Glazebrook, J., Rogers, E. E., Ausubel, F. M. (1996) Isolation of *Arabidopsis* mutants with enhanced disease susceptibility by direct screening. *Genetics* 143, 973-982.
- Glazebrook, J., Rogers, E. E., Ausubel, F. M. (1997a) Use of *Arabidopsis* for genetic dissection of plant defense. *Ann. Rev. Gen.* 31, pp.547-570.
- Glazebrook, J., Zook, M., Mert, F., Kagan, I., Rogers, E. E., Crute, I. R., Holub, E. B., Hammerschmidt, R., Ausubel, F. M. (1997b) Phytoalexin deficient mutants of *Arabidopsis* reveal that *PAD4* encodes a regulatory factor and that four *PAD* genes contribute to downy mildew resistance. *Genetics* 146, 381-392.
- Gonzalez, F. A., Seth, A., Raden, D. L., Bowman, D. S., Fay, F. S., Davis, R. J. (1993) Serum-induced translocation of mitogen-activated protein kinase to the cell surface ruffling membrane and the nucleus. *J. Cell Biol.* 122, 1089-1101.
- Greenberg, J. T. (1997) Programmed cell death in plant-pathogen interactions. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 48, 525-545-275.
- Grosskopf, D. G., Felix, G., Boller, T. (1990) K252a inhibits the response of tomato cells to fungal elicitor *in vivo* and their microsomal protein kinase *in vitro*. *FEBS Lett.* 275, 177-180.
- Gustin, M. C., Albertyn, J., Alexander, M., Davenport, A. (1998) MAP kinase pathways in the yeast *Saccharomyces cerevisiae*. *Microbiol. Mol. Biol. Rev.* 62, 1264-1300.
- Guthrie, C., Fink, G. R. (1991) Guide to Yeast genetics. *Methods in Enzymologie* Vol. 194, Academic press, London.
- Hahlbrock, K. (1975) Further studies on the relationship between the rates of nitrite uptake, growth and conductivity changes in the medium of plant suspension cultures. *Planta* 124, 311-318.
- Hahlbrock, K., Scheel, D., Logemann, E., Nürnberger, T., Parniske, M., Reinold, S., Sacks, W., Schmelzer, E. (1995) Oligopeptide elicitor -mediated defense gene activation in cultured parsley cells. *Proc. Natl. Acad. Sci. USA* 92, 4150-4157.
- Hahn, M. G. (1996) Microbial elicitors and their receptors in plants. *Ann. Rev. Plant Physiol. Plant Mol. Biol.* 47, 387-412.

- Hammond-Kosack, K. E., Jones, J. D. G. (1996) Resistance gene-dependent plant defense responses. *Plant Cell* 8, 1773-1791.
- Hammond-Kosack, K. E., Jones, J. D. G. (1997) Plant disease resistance genes. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 48, 575-607.
- Hanania, U., Avni, A. (1997) High affinity binding site for ethylene inducing xylanase elicitor in *Nicotiana tabacum* membranes. *Plant J.* 12, 113-120.
- Hartmann, U., Valentine, W. J., Christie, J. M., Hays, J., Jenkins, G. I., Weisshaar, B. (1998) Identification of UV/blue light-responsive elements in the *Arabidopsis thaliana* chalcone synthase promoter using a heterologous protoplast transient expression system. *Plant Mol. Biol.* 36, 741-754.
- Haufler, K. D., Hahlbrock, K., Scheel, D. (1986) Elicitor-stimulated furanocoumarin biosynthesis in parsley cells: S-adenosyl-L-methionine:bergapton and S-adenosyl-L-methionine:Xantholol-O-methyltransferases. *Z. Naturforsch.* 41c, 228-239.
- Heasley, L. E., Johnson, G. L. (1992) The β PDGF receptor induces neuronal differentiation of P12 cells. *Mol. Biol. Cell* 3, 545-553.
- Heath, M. C. (1998) Apoptosis, programmed cell death and the hypersensitive response. *Eur. J. Plant Pathol.* 104, 117-124.
- Herscovitz, I. (1995) MAP kinase pathways in yeast: for mating and more. *Cell* 80, 187-197.
- Hill, C. S., Treisman, R. (1995) Transcriptional regulation by extracellular signals: Mechanisms and specificity. *Cell* 80, 199-211.
- Hirt, H. (1997) Multiple roles of MAP kinases in plant signal transduction. *Trends Plant Sci.* 2 (1), 11-15.
- Hopp, T. P., Woods, K. R. (1981) Prediction of protein antigenic determinants from amino acid sequences. *Proc. Natl. Acad. Sci. USA* 78, 3824-3828.
- Huang, C.-Y., Ferrell, J. E. (1996) Ultrasensitivity in the mitogen-activated protein kinase cascade. *Proc. Natl. Acad. Sci. USA* 93, 10078-10083.
- Hunter, T., Karin, M. (1992) The regulation of transcription by phosphorylation. *Cell* 70, 375-387.
- Hunter, T., Plowman, G. D. (1997) The protein kinases of budding yeast: six score and more. *Trends Biol. Sci.* 22, 18-21.
- Huttley, A., Phillips A. L. (1995) Gibberellin-regulated expression in oat aleurone cells of two kinases that show homology to MAP kinase and a ribosomal protein kinase. *Plant Mol. Biol.* 27, 1043-1052.

- Innes, R. W. (1998) Genetic dissection of *R* gene signal transduction pathways. *Curr. Opin. Plant Biol.* 1, 299-304.
- Inoye, C., Dhillon, N., Thorner, J. (1997) Ste5 RING-H2 domain: role in Ste4-promoted oligomerization for yeast pheromone signaling. *Science* 278, 103-106.
- Iwabuchi, K., Li, B., Bartel, P., Fields, S. (1993) Use of the two-hybrid system to identify the domain of p53 involved in oligomerization. *Oncogene* 8, 1693-1696.
- Jabs, T. (1994) Beteiligung von elicitorresponsiven Ionenkanälen an der Signaltransduktion zur Aktivierung der Pathogenabwehr in Petersilie. Dissertation an der Universität Tübingen.
- Jabs, T., Dietrich, R. A., Dangl, J. L. (1996) Extracellular superoxide initiates runaway cell death in an *Arabidopsis* mutant. *Science* 273, 1853-56.
- Jabs, T., Tschöpe, M., Colling, C., Hahlbrock, K., Scheel, D. (1997) Elicitor-stimulated ion fluxes and O_2^- from the oxidative burst are essential components in triggering defense gene activation and phytoalexin synthesis in parsley. *Proc. Natl. Acad. Sci. USA* 94, 4800-4805.
- Jahnen, W., Hahlbrock, K. (1988) Cellular localization of nonhost resistance reactions of parsley (*Petroselinum crispum*) to fungal infection. *Planta* 173, 197-204.
- James, P., Halladay, J., Craig, E. A. (1996) Genomic libraries and a host strain designed for highly efficient two-hybrid selection in yeast. *Genetics* 144, 1425-1436.
- Jonak, C., Kiegerl, S., Ligterink, W., Barker, P. J., Huskisson, N. S., Hirt, H. (1996) Stress signaling in plants: a mitogen-activated protein kinase pathway is activated by cold and drought. *Proc. Natl. Acad. Sci. USA* 93, 11274-11279.
- Jonak, C., Kiegerl, S., Lloyd, C., Chan, J., Hirt, H. (1995) MMK2, a novel alfalfa MAP kinase, specifically complements the yeast MPK1 function. *Mol. Gen. Genet.* 248, 686-694.
- Jonak, C., Ligterink, W., Hirt, H. (1999) MAP kinases in plant signal transduction. *Cell. Mol. Life Sci.* 55, 204-213.
- Jonak, C., Páy, A., Bögre, L., Hirt, H., Heberle-Bors, E. (1993) The plant homolog of MAP kinase is expressed in a cell cycle-dependent and organ-specific manner. *Plant J.* 3, 611-617.
- Joosten, M. H. A. J., Cozijnsen, T. J., Wit, P. J. G. M. (1994) Host resistance to a fungal tomato pathogen lost by a single base pair change in an avirulence gene. *Nature* 367, 384-386.

- Jouannic, S., Hamal, A., Leprince, A. S., Tregear, J. W., Kreis, M., Henry, Y. (1999a) Characterisation of novel plant genes encoding MEKK/STE11 and RAF-related protein kinases. *Gene* 229, 171-181.
- Jouannic, S., Hamal, A., Leprince, A. S., Tregear, J. W., Kreis, M., Henry, Y. (1999b) Plant MAP kinase kinase kinase structure, classification and evolution. *Gene* 233, 1-11.
- Kalunki, T., Deng, T., Hibi, M., Karin, M. (1996) c-Jun can recruit JNK to phosphoralyte dimerization partners via specific docking interactions. *Cell* 87, 929-939.
- Kamada, Y., Muto, S. (1994) Protein kinase inhibitors inhibit stimulation of inositol phospholipid turnover and induction of phenylalanine ammonia-lyase in fungal elicitor-treated tobacco suspension culture cells. *Plant Cell Physiol.* 35 (3), 405-409.
- Kamoun, S., Huitema, E., Vleeshouwers, V. G. A. A. (1999) Resistance to oomycetes: a general role for the hypersensitive response? *Trends Plant Sci.* 4 (5), 196-200.
- Karin, M. (1995) The regulation of AP-1 activity by mitogen-activated protein kinases. *J. Biol. Chem.* 270, 16483-16486.
- Kauss, H., Jeblick, W., Domard, H. (1989) The degree of polymerization and N-acetylation of chitosan determine its ability to elicit callose formation in suspension cells and protoplasts of *Catharanthus roseus*. *Planta* 178, 385-392.
- Kawalleck, P., Keller, H., Hahlbrock, K., Scheel, D., Somssich, I. E. (1993) A pathogen-responsive gene of parsley encodes tyrosine decarboxylase. *J. Biol. Chem.* 268, 2189-2194.
- Kawalleck, P., Schmelzer, E., Hahlbrock, K., Somssich, I. E. (1995) Two pathogen-responsive genes in parsley encode a tyrosine-rich hydroxyproline-rich glycoprotein (hrgp) and an anionic peroxidase. *Mol. Gen. Genet.* 247 (4), 444-452.
- Keller, T., Damude, H. G., Werner, D., Doerner, P., Dixon, R. A., Lamb, C. (1998) A plant homolog of the neutrophil NADPH oxidase gp91^{phox} subunit gene encodes a plasma membrane protein with calcium binding motifs. *Plant Cell* 1998 10, 255-266.
- Keyse, S. M. (1998) Proteinphosphatases and the regulation of MAP kinase activity. *Semin. Cell Dev. Biol.* 9, 143-152.
- Khokhlatchev, A. V., Canagarajah, B., Wilsbacher, J., Robinson, M., Atkinson, M., Goldsmith, E., Cobb, M. H. (1998) Phosphorylation of the MAP kinase ERK2 promotes its homodimerization and nuclear translocation. *Cell* 93, 605-615.

- Kieber, J. J., Rothenberg, M., Roman, G., Feldman, K. A., and Ecker, J. R. (1993) *CTR1*, a negative regulator of the ethylene response pathway in arabidopsis, encodes for a member of Raf family of protein kinases. *Cell* 72, 427-441.
- Knogge, W. (1996) Fungal infection in plants. *Plant Cell* 8, 1711-1722.
- Kombrink, E., Hahlbrock, K. (1986) Responses of cultured parsley cells to elicitors from phytopathogenic fungi. *Plant Physiol.* 81, 216-221.
- Kombrink, E., Somssich, I. E. (1995) Defense responses of plants to phytopathogens. In: *Advances in botanical Research*. Vol. 21 (Andrews, J. H. and Tommerup, I. C., eds.), Academic Press, London, pp. 1-34.
- Kombrink, E., Somssich, I. E. (1997) Pathogen-related proteins and plant defense. In: *The Mycota, Part A, Plant Relationships* (Carroll, G., Tudzynski, P., eds.), Springer Verlag, Berlin, pp. 107-128.
- Korfhage, U., Trezzini, G. F., Meier, I., Hahlbrock, K., Somssich, I. (1994) Plant homeodomain protein involved in transcriptional regulation of a pathogen-related gene. *Plant Cell* 6, 695-708.
- Kortenjann, M., Thomae, O., Shaw, P. E. (1994) Inhibition of *v-Raf* dependent *c-fos* expression and transformation by a kinase defective mutant of the mitogen-activated protein kinase ERK2. *Mol. Cell. Biol.* 14, 4815-4823.
- Kramer, B., Kramer, W., Fritz, H. J. (1984) Different base/base mismatches are corrected with different efficiencies by methyl-directed DNA mismatch-repair system of *E. coli*. *Cell* 38, 879-887.
- Kroj, T. (1995) Untersuchungen zur Rolle der Jasmonsäure als Signalsubstanz bei der Aktivierung der Pathogenabwehr in Petersilie. Diplomarbeit an der Universität Köln.
- Laemmli, U. K. (1970) Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* 227, 680-685.
- Lamb, C., Dixon, R. A. (1997) The oxidative burst in plant disease resistance. *Annu. Rev. Plant Physiol. Plant Mol. Biol.* 48, 251-275.
- Lee, J. H., van Montagu, M., Verbruggen, N. (1999) A highly conserved kinase is an essential component for stress tolerance in yeast and plant cells. *Proc. Natl. Acad. Sci. USA* 96, 5873-5877.
- Leeuw, T. A., Wu, C., Schrag, J. D., Whiteway, M., Thomas, D. Y., Leberer, E. (1998) Interaction of a G β -subunit with a conserved sequence in Ste20/PAK family protein kinases. *Nature* 391, 191-195.

- Legendre, L., Heinsteins, P. F., Low, P. S. (1992) Evidence for the participation of GTP-binding proteins in elicitation of the rapid oxidative burst in cultured soybean cells. *J. Biol. Chem.* 267, 20140-20147.
- Lenormand, P., Sardet, C., Pages, G., L'Allemain, G., Brunet, A., Pouyssegur, J. (1993) Growth factors induce nuclear translocation of MAP kinase (p42^{mapk} and p44^{mapk}) but not of their activator MAP kinase kinase (p45^{mapkk}) in fibroblasts. *J. Cell Biol.* 122, 1079-88.
- Levine, A., Tenhaken, R., Dixon, R., Lamb, C. (1994) H₂O₂ from the oxidative burst orchestrates the plant hypersensitive disease resistance response. *Cell* 79, 583-593.
- Lewis, T. S., Shapiro, P. S., Ahn, N. G. (1998) Signal transduction through MAP kinase cascades. *Adv. Cancer Res.* 74, 49-139.
- Ligterink, W., Kroj, T., zur Nieden, U., Hirt, H., Scheel, D. (1997) Receptor-mediated activation of a MAP kinase in pathogen defense in plants. *Science* 276, 2054-2057.
- Loake, G. J., Factor, O., Lamb, C. J., Dixon, R. A. (1992) Combination of H-box and G-box *cis* elements is necessary for feed-forward stimulation of a chalcone synthase promoter by the phenylpropanoid-pathway intermediate p-coumaric acid. *Proc. Natl. Acad. Sci. USA* 89, 9230-9234.
- Logemann, J., Schell, J., Willmitzer, L. (1987) Improved method for the isolation of RNA from plant tissue. *Anal. Biochem.* 163, 16-20.
- Logemann, E., Wu, S., Schröder J., Schmelzer, E., Somssich, I. E., Hahlbrock, K. (1995) Gene activation by UV light, fungal elicitor or fungal infection in *Petroselinum crispum* is correlated with repression of cell cycle-related genes. *Plant J.* 8, 865-876.
- Loh, Y.-T., Martin, G. B. (1995) The *Pto* bacterial resistance gene and the *Fen* insecticide sensitivity gene encode functional protein kinases with serine/threonine specificity. *Plant Physiol.* 108, 1735-39.
- Lois, R., Dietrich, A., Hahlbrock, K., Schulz, W. (1989) A phenylalanine ammonia-lyase gene from parsley: structure, regulation and identification of elicitor and light responsive *cis*-acting elements. *EMBO J.* 8, 1642-1648.
- MacKintosh, C. (1998) Regulation of cytosolic enzymes in primary metabolism by reversible protein phosphorylation. *Curr. Opin. Plant Sci.* 1, 224-229.
- MacKintosh, C., Lyon, G. D., MacKintosh, R. W. (1994) Phosphatase inhibitors activate anti-fungal defence responses of soybean cotyledons and cell cultures. *Plant J.* 5 (1), 137-147.

- Madhani, H. D., Styles, C. A., Fink, G. R. (1997) MAP kinases with distinct inhibitory functions impart signaling specificity during yeast differentiation. *Cell* 91, 673-684.
- Maher, E. A., Bate, N. J., Ni, J., Elkind, Y., Dixon, C., Lamb, C. (1994) Increased disease susceptibility of transgenic tobacco plants with suppressed levels of preformed phenylpropanoids. *Proc. Natl. Acad. Sci. USA* 1994, 7803-7806.
- Maleck, K., Dietrich, R. A. (1999) Defense on multiple fronts: how do plants cope with diverse enemies? *Trends Plant Sci.* 4 (6), 215-219.
- Manfield, J. W. (1983) Antimicrobial compounds. In: *Biochemical Plant Pathology* (Callow, J. A., ed.), John Wiley & Sons, Chichester, UK, pp. 237-265.
- Mansour, S. J., Matten, W. T., Hermann, A. S., Candia, J. M., Rong, S., Fukasawa, K., Woude, G. F., Ahn, N. G. (1994) Transformation of mammalian cells by constitutively active MAP kinase kinase. *Science* 265, 966-970.
- Marschall, C. J. (1995) Specificity of receptor tyrosine kinase signaling: transient versus sustained extracellular signal-regulated kinase activation. *Cell* 80, 179-185.
- Martin, G. B., Brommonschenkel, S., Chungwongse, J., Frary, A., Ganai, M. W., Spivey, R., Wu, T., Earle, E. D., Tanksley, S. D. (1993) MAP based cloning of a protein kinase gene conferring disease resistance in tomato. *Science* 262, 1432-1436.
- Mathieu, Y., Sanchez, F. J., Droillard, M.-J., Lapous, D., Laurière, C., Guern, J. (1996) Involvement of protein phosphorylation in the early steps of transduction of the oligogalacturonide signal in tobacco cells. *Plant Physiol. Biochem.* 34 (3), 399-408.
- Menke, K. L. H., Parchmann, S., Mueller, M. J., Kijne, J. W., Memelink, J. (1999) Involvement of the octadecanoid pathway and protein phosphorylation in fungal elicitor-induced expression of terpenoid indole alkaloid biosynthetic genes in *Catharanthus roseus*. *Plant Physiol.* 119, 1289-1296.
- Meskiene, I., Bögre, L., Glaser, W., Balog, J., Brandstötter, M., Zwerger, K., Hirt, H. (1998) MP2C, a plant protein phosphatase 2 C, functions as a negative regulator of mitogen activated protein kinase pathways in yeast and plants. *Proc. Natl. Acad. Sci. USA* 95, 1938-1943.
- Millar, J. B., Buck, C., Wilkinson, M. G. (1995) Pyp 1 and Pyp2 PTPases dephosphorylate an osmosensing MAP kinase controlling cell size at division in fission yeast. *Genes Dev.* 9, 2117-2130.
- Minden, A., Lin, A., Smeal, T., Dérijard, B., Cobb, M., Davis, R., Karin, M. (1994) c-Jun terminal phosphorylation correlates with activation of the JNK subgroup but

- not the ERK subgroup of mitogen-activated protein kinases. *Mol. Cell. Biol.* 14, 6683-6688.
- Mithöfer, A., Lottspeich, F., Ebel, J. (1996) One-step purification of the β -glucan elicitor-binding protein from soybean roots and characterisation of an antipeptide antiserum. *FEBS Lett.* 381, 203-207.
- Mizoguchi, T., E., Hayashida, N., Yamaguchi-Shinozaki, K., Kamada, H., Shinozaki, K. (1993) *ATMPKs*: a gene family of plant MAP kinases in *Arabidopsis thaliana*. *FEBS Lett.* 336, 440-444.
- Mizoguchi, T., Gotho, Y., Nishida, E., Yamaguchi-Shinozaki, K., Hayashida, N., Iwasaki, T., Kamada, H., Shinozaki, K. (1994) Characterization of two cDNAs that encode MAP kinase homologues in *Arabidopsis thaliana* and analysis of the possible role of auxin in activating such kinase activities in cultured cells. *Plant J.* 5 (1), 111-122.
- Mizoguchi, T., Ichimura, K., Shinozaki, K. (1997) Environmental stress response in plants: the role of mitogen-activated protein kinases. *Trends Biotechnol.* 15, 15-19.
- Morris, P. C., Guerrier, D., Leung, J., Giraudat, J. (1997) Cloning and characterisation of *MEK1*, an *Arabidopsis* gene encoding a homologue of MAP kinase kinase. *Plant Mol. Biol.* 35, 1057-1064.
- Nennstiel, D., Scheel, D., Nürnberger, T. (1998) Characterization and partial purification of an oligopeptide elicitor receptor from parsley (*petroselinum crispum*). *FEBS Lett.* 431, 405-410.
- Neumann, D., zur Nieden, U., Manteuffel, R., Walter, G., Scharf, K.-D., Nover, L. (1987) Intracellular localization of heat-shock proteins in tomato cell cultures. *Eur. J. Cell Biol.* 43, 71-81.
- Noritake, T., Kawakita, K., Doke, N. (1996) Nitrite oxide induces phytoalexin accumulation in potato tuber tissues. *Plant Cell Physiol.* 37, 113-116.
- Nürnberger, T., Nennstiel, D., Hahlbrock, K., Scheel, D. (1995) Covalent crosslinking of the *Phytophthora megasperma* oligopeptide elicitor to its receptor in parsley membranes. *Proc. Natl. Acad. Sci. USA* 92, 2338-2342.
- Nürnberger, T., Nennstiel, D., Jabs, T., Sacks, W., Hahlbrock, K., Scheel, D. (1994) High-affinity binding of a fungal oligopeptide elicitor to parsley plasma membranes triggers multiple defense responses. *Cell* 78, 449-460.
- Osbourn, A. E. (1996). Preformed antimicrobial compounds and plant defense against fungal attack. *Plant Cell* 8, 1821-1831.

- Parker J. E., Holub, E. B., Frost, L. N., Falk, A., Gunn, N. D., Daniels, M. J. (1996) Characterization of *eds1*, a mutation in *Arabidopsis* suppressing resistance to *Peronospora parasitica* specified by several different *RPP* genes. *Plant Cell* 8, 2033-2046.
- Parker, J. E., Schulte, W., Hahlbrock, K., Scheel, D. (1991) An extracellular glycoprotein from *Phytophthora megasperma* f. sp. *glycinea* elicits phytoalexin synthesis in cultured parsley cells and protoplasts. *Mol. Plant Microbe Interact.* 4, 19-27.
- Parker, J. M. R., Guo, D., Hodges, R. S. (1986) New hydrophilicity scale derived from high-performance liquid chromatography peptide retention data: correlation of predicted surface residues with antigenicity and X-ray-derived accessible sites. *Biochemistry* 25, 5425-5432.
- Payne, D. E., Rossomando, A. J., Martino, P., Erickson, A. K., Her, J.-H., Shabanowitz, J., Hunt, D. F., Weber, M. J., Sturgill, T. W. (1991) Identification of the regulatory phosphorylation sites in pp42/mitogen-activated protein kinase (MAP kinase). *EMBO J.* 10 (4), 885-892.
- Peng, M., Kuc, J. (1992) Peroxidase generated hydrogen peroxide as a source of antifungal activity *in vitro* and on tobacco leaf disks. *Phytopathology* 82, 696-699.
- Phizicky, E. M., Fields, S. (1995) Protein-Protein interactions: Methods for detection and analysis. *Microbiol. Rev.* 59, 94-123.
- Posas, F., Saito, H. (1997) Osmotic activation of the HOG MAPK pathway via Ste11p MAPKKK: scaffold role of Pbs2p MAPKK. *Science* 276, 1702-1705.
- Prell, H. H. (1996) Interaktionen von Pflanzen und phytopathogenen Pilzen. Gustav Fischer Verlag, Jena, Stuttgart.
- Printen, J. A., Sprague, G. F. (1994) Protein-protein interactions in the yeast pheromone response pathway: Ste5 interacts with all members of the MAP kinase cascade. *Genetics* 138, 609-619.
- Pugin, A., Frachisse, J.-M., Tavernier, E., Bligny, R., Gout, E., Douce, R., Guern, J. (1997) Early events induced by the elicitor cryptogin in tobacco cells: involvement of a plasma membrane NADPH oxidase and activation of glycolysis and the pentose phosphate pathway. *Plant Cell* 9, 2077-2091.
- Raz, V., Fluhr, R. (1993) Ethylene signal is transduced via protein phosphorylation events in plants. *Plant Cell* 5, 523-530.

- Renelt, A., Colling, C., Hahlbrock, K., Nürnberger, T., Parker, J. E., Sacks, W., Scheel, D. (1993) Studies on elicitor recognition and signal transduction in plant defence. *J. Ex. Bot.* 44, 257-268.
- Reymond, P., Farmer, E. E. (1999) Jasmonate and salicylate as global signals for defense gene expression. *Curr. Opin. Plant Biol.* 1, 404-411.
- Ricci, P., Bonnet, P., Huet, J.-C., Sallantin, M., Beauvais-Cante, F., Bruneteau, M., Billard, V., Michel, G., Pernollet, J.-C. (1989) Structure and activity of proteins from pathogenic fungi *Phytophthora* eliciting necrosis and acquired resistance in tobacco. *Eur. J. Biochem.* 183, 555-563.
- Ride, J. P. (1983) Cell walls and other structural barriers in defense. In: *Biochemical Plant Pathology* (Callow, J. A., ed.), John Wiley & Sons, Chichester, UK, pp. 215-236.
- Robbins, D. J., Zhen, E. Z., Owaki, H., Vanderbilt, C. A., Ebert, D., Geppert, T. D., Cobb, M. H. (1993) Regulation and properties of extracellular signal-regulated protein kinases 1 and 2 *in vitro*. *J. Biol. Chem.* 268, 5097-5106.
- Robinson, M. J., Cobb, M. H. (1997) Mitogen-activated protein kinase pathways. *Curr. Opin. Cell Biol.* 9, 180-186.
- Robinson, M. J., Stippec, S. A., Goldsmith, E., White, M. A., Cobb, M. H. (1998) Constitutively active ERK2 MAP kinase is sufficient for neurite outgrowth and cell transformation when targeted to the nucleus. *Curr. Biol.* 8, 1141-1150.
- Rogers, E. E., Ausubel, F. M. (1997) Arabidopsis enhanced disease susceptibility mutants exhibit enhanced susceptibility to several bacterial pathogens and alterations in PR-1 expression. *Plant Cell* 9, 305-316.
- Romeis T., Piedras, P., Zhang, S., Klessig, D., Hirt, H., Jones, J. D. (1999) Rapid Avr-9- and Cf-9-dependent activation of MAP kinases in tobacco cell cultures and leaves: convergence of resistance gene, elicitor, wound, and salicylate responses. *Plant Cell* 11, 273-287.
- Rushton, P. J., Somssich, I. E. (1998) Transcriptional control of plant genes responsive to pathogens. *Curr. Opin. Plant Biol.* 1, 311-315.
- Rushton, P., Torres, J. T., Parniske, M., Wernert, P., Hahlbrock, K., Somssich, I. E. (1996) Interaction of elicitor-induced DNA-binding proteins with elicitor response elements in the promoters of parsley PR1 genes. *EMBO J.* 15 (20), 5690-5700.
- Ryals, J. A., Neuenschwanner, U. H., Willits, M. G., Molina, A., Steiner, H. Y., Hunt, M. D. (1996) Systemic acquired resistance. *Plant Cell* 8, 1809-1819.

- Sambrook, J., Fritsch, E. F., Maniatis, T. (1989) *Molecular cloning: A laboratory manual*. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY.
- Schaeffer, H. J., Catling, H. D., Eblen, S. T., Collier, L. S., Krauss, A., Weber, M. J. (1998) MP1: a MEK binding partner that enhances enzymatic activation of the MAP kinase cascade. *Science* 281, 1668-1671.
- Schafstrom, J. P., Altschuler, M., Anderson, D. H. (1993) Molecular cloning and expression of a MAP kinase homolog from pea. *Plant. Mol. Biol.* 22, 83-90.
- Scheel, D. (1991) Plant defense genes. In: *Pesticide chemistry*. (H. Frehse, ed.), VCH, Weinheim, pp. 121-130.
- Scheel, D. (1992) Molecular aspects of host defense response after infection by pathogenic fungi: an overview. In: *Molecular biology of filamentous fungi* (Stahl, U., Tudzynski, P, eds.), VCH-Verlagsgesellschaft, Weinheim, New York, Basel, Cambridge, pp. 125-138.
- Scheel, D. (1998) Resistance response physiology and signal transduction. *Curr. Opin. Plant Biol.* 1, 305-310.
- Schmelzer, E., Krüger-Lebus, S., Hahlbrock, K. (1989) Temporal and spatial patterns of gene expression around sites of attempted fungal infection in parsley leaves. *Plant Cell* 1, 993-1001.
- Schulze-Lefert, P., Dangl, J. L., Becker-André, M., Hahlbrock, K., Schulz, W. (1989) Inducible in vivo footprints define sequences necessary for UV light activation in parsley chalcone synthase gene. *EMBO J.* 8 (3), 651-656.
- Schwacke, R., Hager, A. (1992) Fungal elicitors induce a transient release of active oxygen species from cultured spruce cells that is dependent on Ca²⁺ and protein-kinase activity. *Planta* 187, 136-141.
- Scofield, S. R., Tobias, C. M., Rathjen, J. P., Chang, J. H., Lavelle, D. T., Michelmore, R. W., Stascawicz, B. J. (1996) Molecular basis of gene-for-gene specificity in bacterial speck disease of tomato. *Science* 274, 2063-2065.
- Seo, S., Okamoto, M., Seto, H., Ishizuka, K., Sano, H., Ohashi, Y. (1995) Tobacco MAP kinase: a possible mediator in wound signal transduction. *Science* 270, 1988-1992.
- Seo, S., Sano, H., Ohashi, Y. (1999) Jasmonate-based wound signal transduction requires activation of WIPK, a tobacco mitogen-activated protein kinase. *Plant Cell* 11, 289-298.
- Sharp, J. K., Valent, B., Albersheim, P. (1984) Purification and partial characterization of a β -glucan fragment that elicits phytoalexin accumulation in soybean. *J. Biol. Chem.* 259, 11321-11336.

- Shibuya, N., Ebisu, N., Kamada, Y., Kaku, H., Cohn, J., Ito, Y. (1996) Localization and binding characteristics of a high-affinity binding site for N-acetylchito-oligosaccharide elicitor in the plasma membrane from suspension-cultured rice cells suggest a role as a receptor for the elicitor signal at the cell surface. *Plant Cell Physiol.* 37, 894-898.
- Smith, C. J. (1996) Accumulation of phytoalexins: defence mechanism and stimulus response system. *New Phytol.* 132, 1-45.
- Somssich, I. E. (1994) Regulatory elements governing pathogenesis-related (PR) gene expression. In: *Plant promoters and transcription factors* (Nover, L., ed), Springer-Verlag, Berlin, Heidelberg, pp. 163-179.
- Somssich, I. E., Bollmann, J., Hahlbrock, K., Kombrink, E., Schulz, W. (1989) Differential early activation of defense-related genes in elicitor-treated parsley cells. *Plant Mol. Biol.* 12, 227-234.
- Somssich, I. E., Hahlbrock, K. (1998) Pathogen defense in plants - a paradigm of biological complexity. *Trends Plant Sci.* 3, 86-90.
- Song, W.-Y., Wang, G.-L., Chen, L.-L., Kim, H.-S., Pi, L.-Y., Holsten, T., Gardner, J., Wang, B., Zhai, W., Zhu, L., Fauquet, C., Ronald, P. (1995) A receptor kinase-like protein encoded by the rice disease resistance gene *Xa21*. *Science* 270, 1804-1806.
- Sontag, E., Federov, S., Robbins, D., Cobb, M., Mumby, M. (1993) The interaction of SV40 small tumor antigen with protein phosphatase 2A stimulates the MAP kinase pathway and induces cell proliferation. *Cell* 75, 887-897.
- Stone, J. M., Walker, J. C. (1995) Plant protein kinase families and signal transduction. *Plant Physiol.* 108, 451-457.
- Stratmann, J. W., Ryan, C. A. (1997) Myelin basic protein kinase activity is induced systemically by wounding and increases in response to systemin and oligosaccharide elicitors. *Proc. Natl. Acad. Sci. USA* 94, 11085-89.
- Su, Y-C., Han, J., Xu, S., Cobb, M., Skolnik, E. Y. (1997) NIK is a new Ste20-related kinase that binds NCK and MEKK1 and activates the SAPK/JNK cascade via a conserved regulatory domain. *EMBO J.* 16, 1279-1290.
- Subramaniam, R., Després, C., Brisson, N. (1997) A functional homolog of mammalian protein kinase C participates in the elicitor-induced defense response in potato. *Plant Cell* 9, 653-664.
- Suzuki, K., Fukuda, Y., Shinshi, H. (1995) Studies on elicitor signal transduction leading to differential expression of defense genes in cultured tobacco cells. *Plant Cell Physiol.* 36, 281-289.

- Suzuki, K., Shinshi, H. (1995) Transient activation and tyrosine phosphorylation of a protein kinase in tobacco cells treated with fungal elicitor. *Plant Cell* 7, 639-647.
- Tan, Y., Rouse, J., Zhang, A., Cariati, S., Cohen, P., Comb, M. J. (1996) FGF and stress regulate CREB and ATF-1 via a pathway involving p38 MAP kinase and MAPKAP kinase-2. *EMBO J.* 15, 4629-4642.
- Tang, X. Y., Frederick, R. D., Zhou, J. M., Halterman, D. A., Jia, Y. L., Martin, G. B. (1996) Initiation of plant disease resistance by physical interaction of avrPto and Pto kinase. *Science* 274, 2060-2063.
- Tavernier, E., Wendehenne, D., Blein, J.-P., Pugin, A. (1995) Involvement of free calcium in the action of cryptogein, a proteinaceous elicitor of the hypersensitive reaction in tobacco cells. *Plant Physiol.* 109, 1025-1031.
- Thomma, B. P. H., Eggermont, K., Penninck, I. A. M., Mauch-Mani, B., Vogelsang, R., Cammue, B. P. A., Broekaert, W. F. (1998) Separate jasmonate-dependent and salicylate-dependent defense-response pathways in *Arabidopsis* are essential for resistance to distinct microbial pathogens. *Proc. Natl. Acad. Sci. USA* 95, 15107-15111.
- Thornton, J. M., Edwards, M. S., Tayler, W. R., Barlow, D. J. (1986) Location of 'continuous' antigenic determinants in the protruding regions of proteins. *EMBO J.* 5, 409-413.
- Töpfer, R., Schell, J., Steinbiss, H. H. (1988) Versatile cloning vectors for transient gene expression and direct gene transfer in plant cells. *Nucl. Acids Res.* 16, 8725-8728.
- Torres, M. A., Onouchi, H., Hamada, S., Machida, C., Hammond-Kosack, K. E., Jones, J. D. G. (1998) Six *Arabidopsis thaliana* homologs of the human respiratory burst oxidase (gp91^{phox}). *Plant J.* 14, 365-370.
- Traverse, S., Gomez, N., Paterson H., Marshall, C. J., Cohen, P. (1992) Sustained activation of the MAP kinase cascade may be required for differentiation of P12 cells. *Biochem. J.* 288, 351-355.
- Traverse, S., Seedorf, K., Paterson H., Marshall, C. J., Cohen, P., Ullrich, A. (1994) EGF triggers neuronal differentiation of P12 cells that overexpress the EGF receptor. *Curr. Biol.* 4, 694-701.
- Treisman, R. (1996) Regulation of transcription by MAP kinase cascades. *Curr. Opin. Cell Biol.* 8, 205-215.
- Trewavas, A. J., Malhó, R. (1998) Ca²⁺ signalling in plant cells: the big network. *Curr. Opin. Plant Biol.* 1 (5), 428-433.

- Umemoto, N., Kakitani, M., Iwamatsu, A., Yoshikawa, M., Yamaoka, N., Ishida, I. (1997) The structure and function of a soybean β -glucan binding-protein. Proc. Natl. Acad. Sci. USA 94, 1029-1034.
- Usami, S., Banno, H., Ito, Y., Nishimama, R., Machida, Y. (1995) Cutting activates a 46-kilodalton protein kinase in plants. Proc. Natl. Acad. Sci. USA 92, 8660-8664.
- van de Löcht, U., Meier, I., Hahlbrock, K., Somssich, I. E. (1990) A 125 bp promoter fragment is sufficient for strong elicitor-mediated gene activation in parsley. EMBO J. 9, 2945-2950.
- van den Ackerveken, G. F. J. M., Van Kan, J. A. L., De Wit, P. J. G. M. (1992) Molecular analysis of the avirulence gene *avr9* of the fungal tomato pathogen *Cladosporium fulvum* fully supports the gene-for-gene hypothesis. Plant J. 2, 359-366.
- van der Biezen, E. A., Jones, J. D. (1998) Plant disease resistance proteins and the gene-for-gene concept. Trends Biochem. Sci. 23, 454-456.
- van Lammeren, A. A. M., Keijzer, C. J., Willemse, M. T. M., Kieft, H. (1985) Structure and function of the microtubular cytoskeleton during pollen development in *Gasteria verrucosa* (Mill.) H. Duval. Planta 165, 1-11.
- van Loon, L. C. (1997) Induced resistance in plants and the role of pathogenesis-related proteins. Eur. J. Plant Pathol. 103, 753-765.
- van Loon, L. C., Pierpoint, W. S., Boller, T., Conejero, V. (1994) Recommendations for naming plant pathogenesis-related proteins. Plant Mol. Biol. Rep. 12, 245-264.
- Viard, M. P., Martin, F., Pugin, A., Ricci, P., Blein, J.-P. (1994) Protein phosphorylation is induced in tobacco cells by the elicitor cryptogein. Plant Physiol. 104, 1245-1249.
- Ward, Y., Gupta, S., Wartmann, M., Davis, R. J., Kelly, K. (1994) Control of MAP kinase activation by mitogen-induced threonine/tyrosine phosphatase PAC1. Nature 367, 651-654.
- Weisshaar, B., Armstrong, G. A., Block, A., da Costa e Silva, O., Hahlbrock, K. (1991) Light-inducible and constitutively expressed DNA-binding proteins recognizing a plant promoter element with functional relevance in light responsiveness. EMBO J. 10 (7), 1777-1786.
- Weisshaar, B., Jenkins, G. I. (1998) Phenylpropanoid biosynthesis and its regulation. Curr. Opin. Plant Biol. 1 (3), 251-257.
- Welling, G. W., Wiejer, W. J., van der Zee, R., Welling-Webster, S. (1985) Prediction of sequential antigenic regions in proteins. FEBS Lett. 188, 215-218.

- Wendehenne, D., Binet, M.-N., Blein, J.-N., Ricci, P., Pugin, A. (1995) Evidence for specific high-affinity binding sites for a proteinaceous elicitor in tobacco plasma membranes. *FEBS Lett.* 374, 203-207.
- Wevelsiep, L., Kogel, K. H., Knogge, W. (1991) Purification and characterization of peptides from *Rynchosporium secalis* inducing necrosis in barley. *Physiol. Mol. Plant Pathol.* 39, 471-482.
- Whitmarsh, A. J., Cavanagh, J., Tournier, C., Yasuda, J., Davis, R. J. (1998) A mammalian scaffold complex that selectively mediates MAP kinase activation. *Science* 281, 1671-1677.
- Whitmarsh, A. J., Davis, R. J. (1998) Structural organization of MAP kinase signaling modules by scaffold proteins in yeast and mammals. *Trends Biochem. Sci.* 23, 481-485.
- Wilson, C., Anglmayer, R., Vicente, O., Heberle-Bors, E. (1995) Molecular cloning, functional expression in *Escherichia coli* and characterization of multiple mitogen activated protein kinases from tobacco. *Eur. J. Biochem.* 233, 249-257.
- Wilson, C., Eller, N., Gartner, A., Vicente, O., Heberle-Bors, E. (1993) Isolation and characterization of a tobacco cDNA clone encoding a putative MAP kinase. *Plant Mol. Biol.* 23, 543-551.
- Wirtz, W (1994) Diplomarbeit an der Universität Köln.
- Wong, C., Naumovski, L. (1997) Method to screen for relevant two-hybrid-derived clones by coimmunoprecipitation and colocalization of epitope-tagged fragments - application to Bcl-xL. *Anal. Biochem.* 252, 33-39.
- Woodcock, D. M., Crowther, P. J., Doherty, J., Jefferson, S., DeCruz, E., Noyer-Weidner, M., Smith, S. S., Michael, M. Z., Graham, M. W. (1989) Quantitative evaluation of *E. coli* host strains for tolerance to cytosine methylation in plasmid and phage recombinants. *Nucl. Acids Res.* 17, 3469-3478.
- Xu, S., Cobb, M (1997) MEKK1 binds directly to the c-JUN N-terminal kinases/stress-activated protein kinases. *J. Biol. Chem.* 272 (51), 32056-32060.
- Yang, P., Chen, C., Wang, Z., Fan, B., Chen, Z. (1999) A pathogen- and salicylic acid-induced WRKY DNA-binding activity recognizes the elicitor response element of the tobacco class I chitinase gene promoter. *Plant J.* 18, 141-149.
- Zanke, B. W., Rubie, E. A., Winnett, E., Chan, J., Randall, S., Parsons, M., Boudreau, K., McInnis, M., Yan, M., Templeton, D. J., Woodgett, J. R. (1996) Mammalian mitogen-activated protein kinase pathways are regulated through formation of specific kinase-activator complexes. *J. Biol. Chem.* 271, 29876-29881.

- Zell, R., Fritz, H. J. (1987) DNA mismatch-repair in *E. coli* counteracting the hydrolytic deamination of 5-methyl-cytosine residues. *EMBO J.* 6, 1809-1815.
- Zhang, S., Du, H., Klessig, D. F. (1998) Activation of the tobacco SIP kinase by both a cell wall-derived carbohydrate elicitor and purified proteinaceous elicitors from *Phytophthora* spp. *Plant Cell* 10, 435-449.
- Zhang, S., Klessig, D. F. (1997) Salicylic acid activates a 48-kDa MAP kinase in tobacco. *Plant Cell* 9, 809-824.
- Zhang, S., Klessig, D. F. (1998a) The tobacco wounding-activated protein kinase is encoded by SIPK. *Proc. Natl. Acad. Sci. USA* 95, 7225-7230.
- Zhang, S., Klessig, D. F. (1998b) Resistance gene *N*-mediated *de novo* synthesis and activation of a tobacco mitogen activated protein kinase by tobacco mosaic virus infection. *Proc. Natl. Acad. Sci. USA* 95, 7433-38.
- Zhou, J., Loh, Y.-T., Bressan, R. A., Martin, G. B. (1995) The tomato gene *Pti1* encodes a serine/threonine protein kinase that is phosphorylated by Pto and is involved in the hypersensitive response. *Cell* 83, 925-935.
- Zhou, J., Tang, X., Martin, G. B. (1997) The Pto kinase conferring resistance to bacterial speck disease interacts with proteins that bind a *cis*-element of pathogenesis-related genes. *EMBO J.* 16, 3207-3218.
- Zimmermann, S., Nürnberger, T., Franchisse, J.-M., Wirtz, W., Guern, J., Hedrich, R., Scheel, D. (1997) Receptor-mediated activation of a plant Ca²⁺-permeable ion channel involved in pathogen defense. *Proc. Natl. Acad. Sci. USA* 94, 2751-2755.